COLORADO WATER TRUST

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March 29, 2016

Craig Godbout
Water Supply Planning Section
Colorado Water Conservation Board
1313 Sherman Street, Room 721
Denver, CO 80203

RE: FINAL PROGRESS REPORT
WHITE RIVER-HIGHLAND DITCH DIVERSION PROJECT, YAMPA BASIN
POGGI PDAA 2015 0000000000000164

Dear Craig,

On behalf of the Colorado Water Trust, I am submitting this final progress report, the 30% Design Report (attached) and our final invoice (attached) to the Colorado Water Conservation Board regarding the Yampa/White/Green Basin Roundtable basin funds awarded for the redesign of the Highland Ditch on the White River near Meeker. We are grateful to the CWCB staff and Board as well as members of the Roundtable for making this work possible. Because of your strong support for partnering with private donors and the Ditch Company to figure out how to protect thousands of native fish from dying in the ditch, we now have learned what it will take to make this happen. The Highland Ditch Company's fish protection project would not be possible without the public dollars allocated by the Legislature that are so carefully shepherded by the CWCB. Thank you for your help sharing what we have learned with the rest of the Roundtables.

As you are aware, this project took an unexpected turn. We reported in June that the preliminary design work had revealed an unacceptable flooding risk that required additional hydraulic and predesign analysis. As a result, portions of the WSRA grant funds designated for permitting and final design documents were reallocated to additional preliminary design work. That work has been completed and the results are presented in the attached report "30% Design Report, White River – Highland Ditch Diversion Modification Project (HDDMP)" ("Report"), dated February 2016. The Report recommended maintaining the traditional practice of using a push up dam, contrary to the original conceptual design plan, and installation of a vertical fish screen in the ditch, as further described below.

On March 5, 2016, Carline Bradford, on behalf of the Colorado Water Trust, and other project partners met with the Board of Directors of the Highland Ditch Company to present the Report, discuss its findings, and answer questions. On March 7, the recommendations summarized in the Report were presented at the Shareholders Annual Meeting, where the shareholders unanimously agreed to continue to work with us to design a structure to prevent fish from entering the ditch. The Yampa/White Basin Roundtable was updated at their meeting on March 9. Roundtable members provided many questions as well as support for the transparent process and reporting on the unexpected outcomes and recommendations to the Ditch Company. The Roundtable invited the Ditch Company to submit an application for basin funds for the

Implementation Phase of the project in future and expressed appreciation for the large match from private sources in the project.

BACKGROUND

The Colorado Water Trust was awarded this funding for a multi-purpose project to redesign the Highland Ditch diversion on the White River to address fish passage and fish entrainment concerns while maintaining the full agricultural diversions in accordance with the Highland Ditch's very senior water rights.

The current diversion structure prevents fish migration during the irrigation season by entraining fish, and has the capability to sweep the White River. The existing design of the wing wall and overflow apron at the headgate of the diversion is such that even when a portion of the river water flows back into the main channel of the river, fish are still swept into the Highland Ditch. Once the fish enter the ditch, there is no way for them to return to the river on their own. In average and low water years, the push up dam across the river makes it impossible for any fish to bypass the dam and stay in the river when migrating upstream or downstream. According to Colorado Parks and Wildlife, over 1,000 native and sport fish are stranded and die annually within the Highland Ditch system.

The objective of this project is to develop a new design for the Highland Ditch diversion system that ensures full and efficient agricultural water delivery to the 29 shareholders while minimizing fish entrainment, eliminating aquatic habitat degradation and the barrier to fish migration associated with the annual building of the push up dam across the river. This project assists in meeting the agricultural water supply needs of the basin identified in SWSI 2010 and addresses the non-consumptive needs of the State's threatened and endangered species of the basin identified through the Yampa/White/Green's water supply planning process. These species include the Flannel mouth sucker, Colorado River Cutthroat Trout, and Northern leopard frog.

Prior Tasks - Undertaken with matching funds from other sources

- **Meetings with Stakeholders**- Two diverse stakeholder meetings (September 2014 and April 2015) have taken place along with multiple meetings with CPW, ditch company shareholders, core design team and landowners in the reach. Broad communication continues at every stage in the project process.

- **Data Collection** – including hydraulic survey, base mapping, hydrology, substrate and soil characterization, construction materials characterization is complete.

- **Hydraulic analysis** – including HEC-RAS (existing and proposed), entrainment analysis, scour potential evaluation, sediment transport evaluation, and debris evaluation is complete.

Task 1 – Develop Preliminary Design/Cost Estimates

Colorado Water Trust and its contractors, Flywater, Inc., and OneFish Engineering, have completed with the Preliminary Design and Cost Estimates Task. Consistent with our first progress report, the design team proceeded to address the issues and complexities identified during the predesign work performed during the first 6-month period. The design team evaluated a dynamic structure, including developing a cost estimate for two alternative designs, and recommended the need for additional modeling to reduce performance risk due to the unique topography, hydrology, and interdependent hydraulic variables found at the site. Results were presented to the technical team in June 2015. Review by the technical team raised issues concerning the high estimated costs for construction for all the elements included in the predesign (diversion dam, fish screen, and grade control) relative to the expected benefits. In August, the technical team convened to discuss the results and reach a consensus on the preferred alternative that would best meet the objectives of the project in a cost effective manner. With that information, Flywater and OneFish Engineering finalized their 30% Design Report.

The preferred alternative eliminates certain elements of the designs developed to date, and focuses on the primary objective of the project – to prevent fish entrainment in the ditch. The preferred alternative includes maintaining the current practice of building a push up dam, installing a naturalized fish latter upstream of the headgate to improve upstream and downstream migration during the irrigation season when the push up dam is in place, and installing a vertical fish screen below the headgate and pipe to return the fish to the White River. The design element eliminated was a new diversion dam to replace the push up dam.

<u>Task 2 – Permitting</u>
As noted above, with the permission of the CWCB, funds for permitting, final design and build document tasks were reallocated to hydraulic analysis and preliminary design tasks due to the complexities at the site and increased flooding risk.

<u>Task 3 – Final Design and Build Documents</u>
As noted above, with the permission of the CWCB, funds for permitting, final design and build document tasks were reallocated to hydraulic analysis and preliminary design tasks due to the complexities at the site and increased flooding risk.

Thank you for this opportunity to provide you with this final report on our progress and the use of these grant funds. Please don't hesitate to contact me if you have any questions or would like to review any additional information that has been provided to the shareholders.

In closing, we are so appreciative of the important role of the CWCB staff throughout this project. We want to especially thank Chris Sturm for his participation and guidance at critical decision points. Water projects don't always turn out the way we expect. We are grateful for the opportunity to share our experience with others as well as learn from the collective experience provided by the Roundtable members. Having your active support at the CWCB means so much to us. We couldn't do it without you. Thank you again.

Respectfully submitted by:

Amy Beatie,
Executive Director
COLORADO WATER TRUST

30% Design Report

White River - Highland Ditch Diversion Modification Project (HDDMP)

February 2016

Prepared by:

FlyWater, inc.
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For:
Colorado Water Trust
Colorado Parks and Wildlife
Trout Unlimited

On Behalf of:
Highland Ditch Company Shareholders

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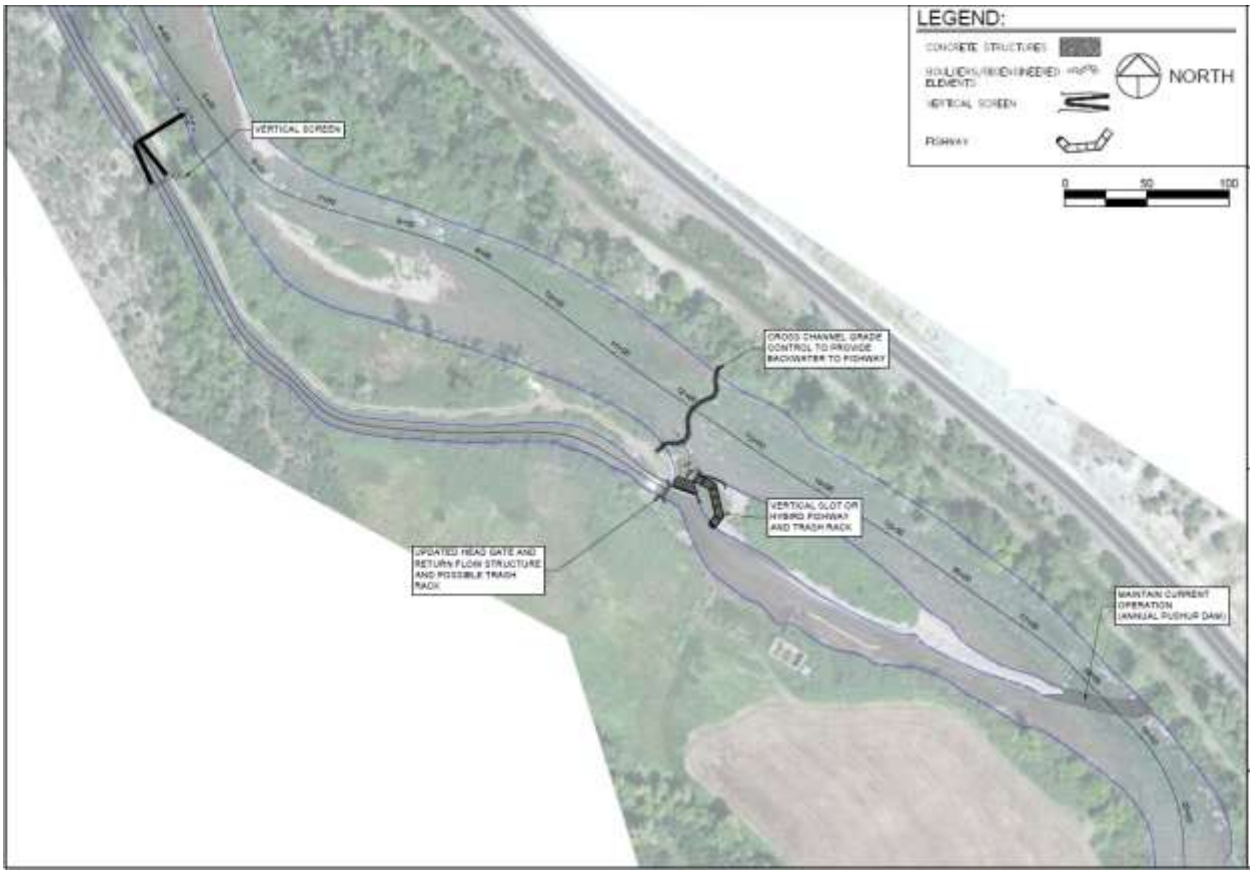
1 INTRODUCTION

The Upper White River basin supports a tremendously important cold-water fishery that is important for both ecological and recreational purposes. Native fish species which are of special concern to both Colorado Parks and Wildlife (CPW) and the U.S. Fish and Wildlife Service (USFWS) that historically occurred within the upper White River basin include Colorado River native cutthroat trout, mountain whitefish, flannelmouth sucker, mountain sucker, mottled sculpin, Colorado pikeminnow and the roundtail chub. Many important non-native fish species have also been legally introduced into the upper White River basin for recreational purposes and those include but are not limited to rainbow, brown, brook, and Snake River cutthroat trout species.

The Highland Ditch diversion is one of the largest irrigation diversions on the upper White River and is of significant concern to Colorado Parks and Wildlife ("CPW") because the existing push up dam that diverts water into the Highland Ditch diversion extends across the entire river channel and poses a significant barrier to fish migration within this section of the White River. In addition, the return flow channel does not allow fish to return to the White river, which results in a significant number of both native and introduced non-native fish species to be entrained into the Highland Ditch irrigation system each year. The Figure below (**Exhibit A)** illustrates the existing conditions at the Highland Ditch diversion. From 2012 through 2015, overall salvage efforts by CPW and the Highland Ditch Company resulted in the salvage of approximately 3,249 fish that were returned to the White River. **Exhibit B** provides a summary of the salvage effort. Unfortunately, the vast majority of the fish entrained into the Highland Ditch become trapped and eventually die from a variety of causes, which is of great concern to CPW and many others.

There was a broad assumption among all shareholders that the recommended design modification to the Highland Ditch Diversion structure would result in suite of recommended physical changes and operational elements that would eliminate the need to build a push up dam every year as part of the agricultural diversion of water into the ditch. Much to the surprise of the design team and stakeholders, this assumption has proved incorrect. After further analysis, it has been determined that the Highland Ditch Company's traditional push up dam practice is effective and does not increase flooding risks as compared to other fixed and dynamic diversion alternatives that have been studied as part of this analysis.

For a variety of reasons that will be explained in this report, the team's recommendation to the Highland Ditch Company includes four main elements. These elements are: 1) Install a vertical fish screen well below the headgate in the ditch to minimize fish entrainment; 2) Install a naturalized fish ladder at the downstream end of the island to enable upstream fish migration during low flows; 3) Reconfigure the existing blocker board grade control structure and rebuild the headgate as part of the fish ladder construction, and 4) Continue the traditional practice of building and removing the push up dam at the upstream end of the island rather than building an alternative permanent diversion structure across the river (see Figure below). Table 1 summarizes the analysis of the pre-design alternatives.



White River-Highland Ditch Division Preferred Design. (Iteration #3)

Table 1: Summary of Pre-Design Alternatives

	Static Diversion/ Coanda Screen	Dynamic Diversion/ Modified Coanda Screen	Dynamic Diversion/ Vertical Screen	Push-up Dam/ Vertical Screen
	Not recommended for further study or consideration			**PREFERRED ALTERNATIVE**
Construction Cost	$1.243M	$1.837M	$1.781M	**$1.023M**
Diversion Dam – Pros		- Reduction of costs of maintaining the push-up dam	- Reduction of costs of maintaining the push-up dam	**-Fish migration occurs unimpeded prior to seasonal construction of push-up dam** **-flooding risk remains the same**
Diversion Dam - Cons	-Increased flooding potential	- Increased flooding potential -An additional $62,750 was recommended to perform additional data collection, analysis, and 3-dimentional modeling	- High cost - Increased flooding potential -An additional $62,750 was recommended to perform additional data collection, analysis, and 3-dimentional modeling	**- No reduction of costs of maintaining the push-up dam**
Screen - Pros	-No moving parts -No external power needed -Self-cleaning -Low Cost -Provides an easy means of bypassing the fish	-No moving parts -No external power needed -Self-cleaning	-Less flooding potential than Coanda screen -Uses similar infrastructure as existing headgate and overflow weir -Significantly less fish bypass flow required (≈ 3 cfs) -Known performance history	**-Less impact on flooding potential** **-Utilizes similar infrastructure as existing headgate and overflow weir.** **-Significantly less fish bypass flow required (≈ 3 cfs)**

	Static Diversion/ Coanda Screen	Dynamic Diversion/ Modified Coanda Screen	Dynamic Diversion/ Vertical Screen	Push-up Dam/ Vertical Screen
	screen to deliver water -Provides easy means of controlling flow into the ditch			**-Known performance history**
Screen - Cons	-Requires high bypass flows which exacerbates flooding risk -Requires more driving head to deliver water right to ditch	-Requires high bypass flows for fish protection (≈ 95 cfs) which exacerbates flooding risk -Overbank excavation -Requires realtime flow management via an adjustable, lateral weir that may require power. -Re-alignment makes bypass of fish screen and flow control into the ditch complex -Large bypass flow is likely a fish attraction flow that deters from effectiveness of secondary fish (intake channel) passage structure -Self-cleaning ability is reduced due to introduction of fish bypass chute	-More expensive than Coanda screen -Fish bypass pipe backwater potential	**-More expensive than Coanda screen** **-Fish bypass pipe backwater potential**

	Static Diversion/ Coanda Screen	Dynamic Diversion/ Modified Coanda Screen	Dynamic Diversion/ Vertical Screen	Push-up Dam/ Vertical Screen
Summary	-Not technically feasible at the Highland Ditch location due to in adequate driving head to deliver the full decreed amount to the ditch -Piping water from the Coanda screen through the canal dike found to not be feasible	-Increased flooding potential make the project risks too high -Project estimated costs outweighed the benefits	-Increased flooding potential make the project risks too high -Project estimated costs outweighed the benefits	**-Fish screening will prevent entrainment of fish within the Highland Ditch** **-Annual push-up dam practices do not increase flooding potential** **-Improved fishery connectivity during low flow events**

1.1 Purpose and Need

As originally proposed, the purpose of the White River-Highland Ditch Modification Project ("the Project") was to develop final engineering designs for replacement of the diversion structure and headgate using a modern agricultural diversion system. The design was to ensure full and efficient water delivery to the shareholders while significantly minimizing fish entrainment into the ditch and eliminating aquatic habitat degradation and barriers to fish migration associated with the annual building of the push up dam across the river. The objectives of the project included:

- Protect thousands of fish from becoming entrained in the Highland Ditch by incorporating a modern fish screen into the diversion's design.

- Protect aquatic habitat and restore connectivity within the White River from impacts of building a push up dam each spring and removing the push up dam each fall by replacing the push up dam with a permanent, fish passable diversion structure.

- Provide benefits to the Ditch Company which include the reduction of heavy equipment costs, fuel and labor costs, and risk associated with maintaining the push up dam.

- Ensure full and efficient water delivery to the Highland Ditch shareholders without negatively impacting water operations.

- Improve the ability to efficiently adjust the amount of water going down the ditch.

- Provide local model of using fish screens to other ditch companies in White/Yampa/Green watersheds.

1.2 Summary of Project Activities

PROJECT TEAM. The project team for this Project consisted of the CPW Meeker office, acting as the primary project leader, ambassador, promoter and coordinator; other local and regional CPW staff; Trout Unlimited; Colorado Water Trust, acting as project fundraiser and liaison between project partners and funders; Flywater, inc., ("Flywater") acting as the contract engineer for the design work; and One Fish Engineering, LLC, ("OneFish) providing technical support for the fish screen portion of the design work.

FUNDING PARTNERS. Funding for the Project was secured from multiple sources to support completion of the following tasks: stakeholder meetings, funder/landowner coordination, and design tasks, including data collection, hydraulic analysis, preliminary design and cost estimates, permitting, and preparation of final design build documents. Funding sources included the CWCB's Water Supply Reserve Account, Trout Unlimited, Elk Creek Ranch, Walton

Family Foundation, and the U.S. Fish and Wildlife Service *Fishing is Fun* grant program administered by Colorado Department of Parks and Wildlife. The initial funding strategy assumed that funding for the construction phase of the project would be developed largely concurrent with the preliminary design process and would depend strongly on local private landowners who would benefit from the project completion and the Yampa/White/Green Basin Roundtable's. Due to the extended timeline needed to complete the expanded predesign analysis, communication with prospective funders has also slowed.

STAKEHOLDER PROCESS/TIMELINE SUMMARY.

2012/2013: CPW spearheaded a cooperative and collaborative effort among the Highland Ditch Company, Trout Unlimited, Colorado Water Trust, FlyWater, Inc., and One Fish Engineering, LLC to minimize fish entrainment in the Highland Ditch.

2014: Outreach to additional stakeholders in the community and prospective funders began in early 2014. Public and private funding partners were secured during 2014 to pay for the assessment and preliminary design. Data collection and hydraulic analysis began in earnest during fall of 2014. Both individual meetings and broad stakeholder group meetings were held to discuss findings and provide feedback.

2015: During the preliminary design phase of the project in early 2015, concerns surfaced over increased flooding risks with the original conceptual design, which consisted of a static diversion dam and Coanda screen. These concerns led to a need for additional hydraulic modeling and analysis. Upon approval from the contracting officer at the CWCB's Water Supply Planning Section by letter dated August 3, 2015, funds originally earmarked for the Permitting and Final Design Build Documents tasks were reallocated to perform additional hydraulic analysis and preliminary design work necessary to address the technical challenges identified. As a result of this work, preliminary designs were developed for additional alternatives to address the technical challenge. The design alternatives are described in **Section 2**. Unanticipated delays in the timeline and expanded review by a broader team of technical stakeholders occurred in late 2015. This expanded assessment and review process slowed the timeline and delayed the determination of a recommended alternative by many months.

2016: Once the expanded technical team agreed on a path forward, this 30% design report was prepared to share with the Highland Ditch Company shareholders. Pending acceptance by the Highland Ditch Company shareholders, this report will be distributed to all stakeholders and funders in early 2016. At that time, next steps will be determined by the Highland Ditch Company shareholders.

2 DESIGN ALTERNATIVES

This section describes the preliminary design of alternatives developed to meet the project goals. A glossary of terms used in this section is provided in **Exhibit H**. Additional information regarding the fish screen designs is provided in the Fish Screen 30% Design Report prepared by OneFish (OneFish Report, see **Exhibit G**).

2.1 Static Diversion Dam/Coanda Screen Alternative

The initial design concept envisioned to accomplish the goals of the project consisted of a static cross channel diversion that would replace the function and need for a push up dam and a Coanda fish screen. The intake channel would remain in its existing configuration, and the Coanda screen would be inserted in the place of the return flow channel located adjacent and perpendicular to the Highland Ditch headgate. The Coanda screen would deliver water into the Highland ditch via a pipe placed through the existing dike on the east side of the canal, while simultaneously excluding fish and preventing entrainment. Additional conceptual elements include a fish ladder incorporated into the Coanda screen to provide a secondary path for fish passage during low flow events, and installation of erosion protection measures and grade control structures within the White River to protect new infrastructure, and create fish passage over the newly installed diversion structure over a range of flow events. The preliminary design drawings for this alternative are provided in **Exhibits C1 and C2.**

This concept appeared to be an elegant solution to achieve the project goals since the existing headgate could act as a Coanda screen bypass if needed. The Coanda screen has no moving parts, does not require power, and is generally self-cleaning. The return flow channel has enough elevation drop from the spill crest to the invert of the receiving channel to make the fish screen operational; thus, delivering fish directly from the intake channel back to the main stem of the White River.

During the preliminary design process for this alternative, we determined that there was not enough driving head to deliver the full amount of the decreed water right through the Coanda Screen with its orientation perpendicular to the headgate and that installing a pipe through the existing canal dike was not feasible. In addition, data analysis and hydraulic modeling indicated that flooding potential of this design would increase due to the combined effects of the static diversion structure, minimal freeboard of the southern river bank, and the large amount of bypass flow required by the Coanda screen. For these reasons, it was determined that this alternative was not feasible.

2.2 Dynamic diversion dam/Modified Coanda Screen Alternative

To address the issues with the static diversion dam and Coanda screen, an alternative was developed that consists of a modified Coanda screen that would deliver water directly from the intake channel into the ditch, and a dynamic diversion dam that could adjust its crest height to accommodate low flow and high flow operations. Preliminary design drawings are provided in **Exhibit D1 and D3**.

The dynamic diversion dam consists of static and dynamic structures. The static portions of the diversion dam are comprised of the concrete abutments, crest, footer and scour apron. The dynamic portion consists of an adjustable Obermeyer gate incorporated into the dam's crest. An Obermeyer gate consists of a steel plate that is adjustable via pneumatics. The steel plate can be raised and lowered using solar power and would be incorporated into the diversion dam where the White River's thalweg exists. Overall, the diversion dam is approximately 300 linear feet in crest length and ranges from one to four feet above the existing channel's invert, with the Obermeyer gate fully raised. The diversion dam is designed to deliver between 300 and 400 cfs into the intake channel during low flow events, and can effectively sweep the river in with the Obermeyer gate fully raised. During runoff and at higher flows, the Obermeyer gate will be lowered incrementally, as needed.

The Coanda fish screen's alignment was realigned across the ditch at the location of the current headgates to take advantage of driving head forces for better water delivery. The realignment requires rebuilding the existing return flow channel to include an adjustable overflow gate in order to maintain functional flow over the fish screen. In addition, a concrete fish chute is added to send fish back to the White River, and an adjustable lateral weir that can move accordingly to maintain desired flows to achieve the required WSEL for the Coanda screen's concrete fish chute to function property. The same fish passage improvements associated with the Static Diversion Dam/Coanda Screen design are included in this alternative.

HECRAS modeling of this alternative showed that the existence of the diversion dam with the Obermeyer gate completely lowered still caused a rise in water surface elevations ("WSEL") during flooding events. This rise in WSEL is because the cross sectional flow area of the White River's channel was reduced by the diversion dam. We determined that widening the existing channel was not feasible. Due to the complexities uncovered for this project during the preliminary design activities, we determined that the hydraulic modeling tools utilized, which included HECRAS and various flow equations, were not appropriate for the analysis of the complex split flows occurring in varying flow conditions at the Highland Ditch site. HECRAS is a one dimensional flow model broadly used in diversion and fish passage design projects. In the case of this Project, more refined tools such as three dimensional flow modeling would reduce the design risk and ultimately ensure the performance of built structures. For this reason, we recommended that project partners approve an additional $62,750 for additional data collection, analysis, and 3-dimentional modeling to finalize the design work for this alternative.

Estimated costs for the alternative are presented below, and are based on estimated material quantities developed from existing data and professional judgment. The estimates are preliminary in nature. This cost for the additional data collection and modeling is included in the estimated costs below as that work is recommended to proceed with this alternative.

Design Iteration 2 with Modified Coanda Screen and Dynamic Diversion		
Item #		Approx. Cost
1	Dynamic (Obermeyer) Diversion Structure	$ 421,500
2	Primary Fish Passage	$ 159,275
3	Secondary Fish Passage	$ 69,000
4	Modified Coanda Fish Screen, Water Delivery System and Associated Infrastructure	$ 750,000
5	Island Protection	$ 62,700
6	Bank Protection	$ 108,000
	Subtotal	$ 1,570,475
	General Conditions (3%)	$ 47,114
	Contingency (10%)	$ 157,048
	Estimated Total	$ 1,774,637
	Additional Data Analysis and Modeling	$ 62,750
	Estimated Grand Total	$ 1,837,387

2.3 Dynamic Diversion Dam/Vertical Screen Alternative

As a result of operational issues that arose with the modified Coanda screen preliminary design, an alternative that included a vertical screen was developed. The design configuration associated with this alternative is shown in **Exhibits D2.** This configuration consists of the same dynamic diversion as described in Section 2.2, but with a vertical screen located in the ditch below the headgate. The screening area would consist of multiple screen plates approximately 6-feet in length. Diverted water passes through the screen and the debris and fish are swept to the downstream end of the screen through a combination of sweeping flow and brushes. Fish will be returned to the White River below the push up dam structure through a pipe that empties into a receiving site in the river that has appropriate pool depths and velocities needed by the fish. A solar system will provide power to the screen.

Estimated costs for the alternative are presented below, and are based on estimated material quantities developed from existing data and professional judgment. The estimates are preliminary in nature.

Design Iteration 2 with Vertical Fish Screen and Dynamic Diversion		
Item #		Approx. Cost
1	Dynamic (Obermeyer) Diversion Structure	$ 421,500
2	Primary Fish Passage	$ 159,275
3	Secondary Fish Passage	$ 69,000
4	Vertical Fish Screen, Water Delivery System and Associated Infrastructure	$ 700,000
5	Island Protection	$ 62,700
6	Bank Protection	$ 108,000
	Subtotal	$ 1,520,475
	General Conditions (3%)	$ 45,614
	Contingency (10%)	$ 152,048
	Estimated Total	$ 1,718,137
	Additional Data Analysis and Modeling	$ 62,750
	Estimated Grand Total	$ 1,780,887

2.4 Push-Up Dam/Vertical Screen Recommended Alternative

Uncertainty with regards to the additional flooding risk identified with the dynamic diversion dam and the operational issues with the traditional and modified Coanda screen, together with the growing costs for further study and high estimated costs for construction, led to the development of an additional alternative that eliminates the diversion dam structure and uses a vertical screen to prevent fish entrainment into the ditch. Preliminary design drawings for this alternative are provided in **Exhibit3 E1 – E8.**

For this alternative, the current practice of using a push-up dam to divert flows to the inlet channel will be maintained. As analysis of the system progressed through preliminary design, it became evident that the push-up dam practice is hydraulically optimized for the site's specific topographical and hydrologic conditions and use parameters. Because of this, introduction of a permanent diversion structure may not perform better than the current push-up dam practice.

Similar to the alternative described in **Section 2.3**, a vertical screen would be located in the ditch downstream of the Highland ditch headgate. The screening area would consist of multiple screen plates. Diverted water passes through the screen and the debris and fish are swept to the downstream end of the screen through a combination of sweeping flows and brushes. Fish will be returned to the White River through a pipe that empties into a receiving site in the river that has appropriate pool depths and velocities needed by the fish. A solar system will provide power to the screen

During this preliminary design phase, different screen sizes were evaluated to optimize costs and benefits. With input from the stakeholder group, the screen size selected for this alternative was based on maintaining an approach velocity of 0.6 ft/sec at flows of 250 cfs. Historical diversions are typically around 230 cfs in June, and approximately 150 cfs in

September. This screen size will screen fish in the range of 2 inches without injury. Additional information regarding screen selections is presented in **Exhibit G (OneFish Report)**.

The existing headgate is functional although very old. It is recommended that the existing headgate be rebuilt as there will be significant changes to the concrete blocker board structure (overflow) adjacent to the headgate during construction of the fish ladder. It may simply be more efficient to rebuild the headgate altogether rather than trying to save portions of the old concrete and tie in the new structure with the old structure. A naturalized fish ladder will be installed adjacent to the return flow channel to improve upstream and downstream migration during irrigation season when the push up dam is in place throughout the period when flows in the river are greater than the amount being diverted into the Highland Ditch. Additional improvements associated with erosion control and aquatic habitat are included in this Alternative.

Estimated costs for the alternative are presented below, and are based on estimated material quantities developed from existing data and professional judgment. The estimates are preliminary in nature.

Design Iteration 3 Preferred Design with Vertical Fish Screen		
Item #		Approx. Cost
1	Rebuilt Headgate and Return Flow Channel	$ 70,000
2	Fish Passage (Ladder)	$ 70,000
3	Vertical Fish Screen, Water Delivery System and Associated Infrastructure	$ 700,000
4	River Channel and Bank Improvements	$ 65,000
	Subtotal	$ 905,000
	General Conditions (5%)	$ 27,150
	Contingency (10%)	$ 90,500
	Estimated Total	$ 1,022,650

2.5 Analysis of Alternatives

While the original conceptual design of a static diversion dam and Coanda screen was attractive due to its low cost and low maintenance, during the preliminary design process, the alternative was ultimately determined not to be technically feasible due to the increase in flooding risk. This risk resulted from the combined effects of that static diversion structure, minimal freeboard of the southern river bank, and the large amounts of flow required to enter the intake channel in order to deliver the full decreed amount of water to the Highland Ditch, bypass of senior downstream water rights, and provide for adequate flows for the Coanda Screen and fish passage elements to work.

In addition, Rio Blanco County is in the process of producing detailed 100-year floodplain mapping in the project area. This mapping increases risk of easily securing a permit for the project due to potential flooding concerns.

To address the increase flooding risk, two alternatives were developed that incorporate an Obermeyer adjustable gate, which can be lowered as flows increase. The first option included a modified Coanda screen to replace the traditional Coanda Screen, and the second option included a vertical screen. HECRAS modeling performed with the diversion dam completely lowered still showed an increase in flooding risk due to the reduced cross sectional flow area of the White River's channel caused by construction of the diversion dam.

For the modified Coanda screen alternative, the screen was realigned with the ditch in order to deliver the necessary flows to the ditch. The preliminary design phase work concluded that this alignment created additional complexities that made the additional costs associated with a vertical screen more attractive. The increase in estimated costs of these alternatives combined with the flooding risk identified by the HECRAS modeling let to a recommendation to perform additional data collection, 3-dimentional modeling, and further design of project components. The additional costs of these work was estimated to be $62,750.

With both design and construction costs escalating, the stakeholder group sought an alternative that would be more cost effective, recognizing that all the project goals may not be able to be met.

Table 1 summarizes the costs, and detailed pros and cons of the alternatives developed during the primary design phase of the Project.

After careful consideration and analysis of the alternatives, the stakeholder group opted to move forward with the alternative that maintains the push-up dam and installs a vertical fish screen in the ditch. The group determined that the preliminary cost estimates that include all the project elements was too expensive for the expected benefits, given the current health of the White River fishery. The vertical screen was chosen because it requires less bypass flow than the Coanda screen, it can be located within the ditch, it is less expensive than the modified Coanda screen, and its operation and performance is known. General operation and maintenance expectations for the vertical fish screen are located in Exhibit I.
The dynamic diversion dam was removed from the design due to the high unanticipated costs for design and construction due to the increased flooding risk caused by the unique aspects of the site. The push-up dam is only in place during a portion of the irrigation season in average and low flow years and therefore only blocks fish migration during a portion of the year. During the time that the traditional push-up dam is not in place, fish are still able to move freely upstream and downstream through this reach. Given the analysis to date, it was determined that the new diversion structure may not provide greater benefits to fish migration than the current push-up dam and in fact, may negatively impact the status quo. Installing a permanent structure across the full width of the river may increase flooding risk on private property upstream of the headgate, creating an unacceptable risk, particularly in light of the Rio Blanco

flood plain mapping currently underway. Additionally, a permanent diversion structure would not meet the project objective of improving fish migration more than the status quo practice of creating a temporary barrier combined with a new permanent fish ladder for fish to use during the irrigation season.

2.6 Cost estimate for Final Design and Construction

Given the existing body work, FlyWater, inc. believes additional funds are necessary to complete the final design (90%) and deliverables. The table below shows the estimated costs for the additional scope of services and the estimated cost for construction of the preferred alternative.

FINAL DESIGN		
Task #	**Description**	**Approx. Cost**
1	Final Design of Vertical Fish Screen	$8,000
2	Final Design of Rebuilt Headgate and Return Flow Channel	$5,000
3	Final Design of Fish Passage	$5,000
4	Final Design of Design of Aquatic Habitat Improvements	$3,000
5	Final Design of Erosion Control Improvements	$5,000
6	Permitting Coordination and Submittals (ACOE, DWR)	$10,000
7	Final Design Report	$6,500
8	Construction Bid Documents and Specifications	$9,500
9	Project Management and Stakeholder Coordination	$10,500
10	Project Fundraising	$20,000
	Total	$82,500
CONSTRUCTION		
	Push-Up Dam/Vertical Screen	$ 1,022,650
GRAND TOTAL		**$ 1,105,150**

3 DATA COLLECTION AND ANALYSIS

Following is a technical narrative of the work completed to date and is presented in manner that is relevant to the project design services accomplished.

3.1 Diversion Operations

The Highland Ditch irrigation system is approximately eight miles total in length from the point of diversion on the White River east of Meeker to the end point where the irrigation water flows back into Flag Creek, and eventually back into the White River near Meeker.

Currently, water is diverted in low flow events by using heavy equipment to construct a pushup dam from native bed material. The pushup dam is constructed in such a way that it sweeps the flow of the White River into the intake channel. Blocker boards at the top of the return flow channel assist with water delivery into the ditch during low flows. Blocker boards are an effective method for improving water diversion, but they also promote fish entrainment into the ditch. The pushup dam has to be removed before high flow periods in order to prevent flooding. This process occurs annually. **Exhibit A** found in the appendix shows the diversion project area.

3.2 Data Collection

3.2.1 Literature and Data Review

Water rights information, and fish salvage data were assessed as part of the initial literature and data review. Water rights information was acquired from the CDSS (Colorado Decision Support System) and the CPW. Information included the decreed water right for the Highland Ditch intake structure, historic daily diversion records, and shareholder information. Fish Salvage data was taken from the CPW's 2012 through 2015 Highland Ditch Fish Salvage Program Summary. Bureau of Reclamation guidance on various fish protection methods was consulted to inform the development of options.

3.2.2 HOBO Installation

One Fish Engineering installed two stage measurement devices (HOBOs) to gage the relative water surface elevations in Highland Ditch versus the intake channel. The devices were deployed on 7/14/2014 and recorded stage data continuously until they were removed on 10/6/2014. Flow measurements were taken using an acoustic Doppler flow gage in both the ditch and intake channel on 7/14 and 10/6 as well. Data was used to determine available driving head for evaluation of various types of fish screens.

3.2.3 Hydraulic Survey

An in-channel hydraulic survey was conducted on 8/13/14 to determine the physical characteristics of the White River, the intake channel, the Highland ditch, and the headgate structure and return flow channel. Continuous thalweg elevations were measured on the White River starting approximately 400’ downstream from the ranch access bridge, extending approximately 1500' downstream. Thalweg elevations were measured in the intake channel, and continued downstream past the headgate approximately 150' down the ditch. Several cross sections were taken on the White and intake channel through the entire project area, and one typical cross section of the ditch was collected. Several spot elevations on the head gate structure, stop log dam, and return flow apron were collected as well. The survey was conducted by conventional means using a total station. Surveyed elevation data is relative and is not tied to any published benchmark information.

3.2.4 Basemapping

A project base drawing was created in ACAD using Google Earth Aerial imagery and survey data. Aerial imagery was adjusted to NAD 83 Colorado North, State Plane coordinates by referencing NGS benchmark KL0572; however, the adjustment was made visually in ACAD and should be taken as approximate. Survey data of points on known features (i.e. Ranch access bridge, and headgate structure) were used to scale aerial imagery.

3.2.5 Hydrology

Flows for the White River at the Highland Ditch project site were evaluated using two methods. First, regional regression equations were applied using the USGS StreamStats web application. This method yielded the following peak flows.

Flow Frequency	Flow (cfs)
Q_2	3640
Q_5	4790
Q_{10}	5620
Q_{25}	6020
Q_{50}	7050
Q_{100}	7730
Q_{200}	8280
Q_{500}	9040

In addition to the regression equation, a Log-Pearson frequency analysis was performed for USGS streamgage 09304200 "White River Above Coal Creek Near Meeker, CO". The gage is approximately 2.3 miles down from the project site, so flows were scaled down slightly based on drainage area. The contributing drainage area at the project site is approximately 640 mi^2; drainage area at gage 9304200 is 648 mi^2. This results in a scaling factor of 0.988. In February

2015 scaled Log-Pearson flows were shared with the stakeholder group that were scaled by a factor of 0.842. These values were in error. Upon revisiting the published USGS gage description, it was discovered that the contributing basin area for gage 09304500 (760 mi^2) was mistakenly used in generating the scaling factor. The result is that estimated flows are actually about 15% higher than the values reported in February. The following table presents both the corrected and errant flows based on scaled Log-Pearson frequency results.

Flow Frequency	**Corrected Flow (cfs)**	Errant value (reported in Feb)
$Q_{1.25}$	**1985**	1688
Q_2	**2953**	2990
Q_5	**4109**	3503
Q_{10}	**4760**	4058
Q_{25}	**5472**	4665
Q_{50}	**5936**	5061
Q_{100}	**6351**	5414
Q_{200}	**6726**	5734

3.2.6 Substrate and Soils Characterization

White River substrate appears to be fairly well-armored and is comprised of river cobble as well as sand and silt. From field inspection and review of site photos, it is estimated that the D_{50} of the bed material is on the order of 4” to 6" with many large boulders present predominantly along the north bank near the toe of the slope. Substrate in Highland ditch itself is smaller and has a larger percentage of fines and silts due to lower grades and velocities. Ditch substrate is estimated to have the D_{50} on the order of 3"to 5". Substrate in both the river and the ditch are likely mobile during higher flows and runoff. Substrate classification is anecdotal based on observations made during the field channel survey. No samples were collected and no gradation analysis was performed.

The White River valley in the vicinity of the project site is agricultural and predominantly made up of well drained, to somewhat poorly drained loam and clay. Classifications include Shaw loam, Zoltay clay-loam, and Redrob loam. Upland areas are typically well drained soils; classifications include Jerry-Thornburg-Rhone, and Blazon-Rentsac.

3.3 Hydraulic Analysis

3.3.1 Existing Conditions HEC-RAS

Data collected in the hydraulic survey was used to build a one dimensional hydraulic model of existing conditions using the Army Corps of Engineers standard step backwater program HEC-RAS version 4.0 (Hydrologic Engineering Center's River Analysis System). Survey data was limited to the channel and immediate banks. Cross sections were augmented in the overbank with USGS DEM topography derived from Google Earth in order to contain flows in the floodplain. Rio Blanco County has collected LIDAR topography for use in the upcoming mapping associated with the NFIP (National Flood Insurance Program) detailed floodplain study; however, for preliminary modeling it was not utilized.

Flow at gage 09304200 on the day of the survey was 352 cfs, flow at the site was adjusted by area as outlined in the hydrology section, and flow at the site was determined to be 296 cfs. Based on engineering judgment and water surface elevations measured during the survey, Manning's N roughness values were taken to be 0.035 in the main channel and 0.07 in the overbank. The percentage of flow entering the intake channel was determined to be approximately 80 cfs by iterating until water surfaces in the main channel and intake channel matched at the upstream end. Flow actually being drawn into the ditch at the turnout was taken to be approximately 35 cfs based on a conversation with the ditch rider.

In addition to the calibration flow from the date of the survey, the existing conditions model was run for the following flows, which are based on hydrologic results from both the USGS regression and the Log-Pearson frequency analysis:

Flow Frequency	Flow (cfs)
$Q_{1.25}$	2030
Q_2	3000
Q_5	4160
Q_{25}	5540

Existing conditions HEC-RAS modeling indicated that flooding into the agricultural area on the south side of the river would likely occur as frequently as in the 2-year event. Discussions with the ditch company indicated that they closely monitor water levels each year and carefully time when to remove the pushup dam in order to avoid flooding. Initially, two proposed scenarios were run in order to determine if grading the intake channel to be wider or deeper would improve the potential flooding issue. Modeling for the width increase indicated that if the intake channel was widened by 36' up to the 2-year event might be contained but not much more than that. Modeling for the depth increase showed decreased water surfaces for flows less than the 2-year event, but didn't provide much relief at the 2-year or higher even when the channel depth was increased by 2.38'. This is likely due to the backwater effect from the downstream end of the intake channel combined with the fact that deepening the intake increases the amount of flow that splits toward the intake.

3.3.2 Proposed Conditions HEC-RAS

HEC-RAS modeling was performed for a proposed condition having an updated diversion structure and a Coanda style fish screen. In this configuration, the minimum design intake flow was 459 cfs. Model geometry of just the intake channel and the ditch was run for a range of flows and it was determined that ~ 4.3' of head is required at the upstream end of the intake channel in order to deliver ~ 460 cfs.

Given the potential flooding risk and cost and difficulty of widening the intake channel and or building a levee, the initial concept of building a static diversion that would meet the project goals no longer seemed feasible.

A dynamic gate such as an Obermeyer was considered as potential option that would provide low maintenance and low flow fish passage. Access to power at the project site is a limiting factor, i.e. 150 square feet is the approximate maximum size for which an Obermeyer gate can be solar powered.

The proposed diversion structure was modeled in HEC-RAS as a blocked obstruction leaving an open area approximately 4.4' deep by 34' wide to represent the gate fully open. This model was then run to determine potential flood elevation impacts over the same range of flows evaluated in the existing conditions model. The following table summarizes flow splits and water surface elevations for the existing condition versus a proposed configuration with an Obermeyer gate in the fully opened position, and a Coanda style fish screen. Please refer to **Exhibit F**: Plan View Cross Sections for the location of cross sections.

INTERVAL	EXISTING CONDITION Q (Upstream)	Q Mainstem	Q intake	Q ditch	PROPOSED CONDITION Q (Upstream)	Q Mainstem	Q intake	Q ditch	DELTA Q intake
	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
Calib	296	215	81	35	296	215	81	35	0
Design	1057	682	375	250	1057	670	387	250	12
Q1.25	2030	1240	790	250	2030	1173	857	250	67
Q2	3000	1600	1400	250	3000	1400	1600	250	200
Q25	5540	2920	2620	250	5540	2862	2678	250	58

INTERVAL	XSEC	LOCN	EX. WS (ft)	PROP WS (ft)	DELTA (ft)
Calib	1254	d.se end of intake	994.11	994.11	0
Calib	1465	2/3 down intake	994.21	994.33	0.12
Calib	1600	1/3 down intake	994.65	994.67	0.02
Calib	1778	at diversion	994.79	994.81	0.02

INTERVAL	XSEC	LOCN	EX. WS (ft)	PROP WS (ft)	DELTA (ft)
Design	1254	d.se end of intake	991.95	994.84	2.89
Design	1465	2/3 down intake	995.44	995.71	0.27
Design	1600	1/3 down intake	995.97	996.08	0.11
Design	1778	at diversion	996.41	996.51	0.1

INTERVAL	XSEC	LOCN	EX. WS (ft)	PROP WS (ft)	DELTA (ft)
Q1.25	1254	d.se end of intake	992.41	995.42	3.01
Q1.25	1465	2/3 down intake	996.77	997.02	0.25
Q1.25	1600	1/3 down intake	997.09	997.26	0.17
Q1.25	1778	at diversion	997.84	998.05	0.21

INTERVAL	XSEC	LOCN	EX. WS (ft)	PROP WS (ft)	DELTA (ft)
Q2	1254	d.se end of intake	992.95	995.51	2.56
Q2	1465	2/3 down intake	998.56	998.99	0.43
Q2	1600	1/3 down intake	998.65	999.08	0.43
Q2	1778	at diversion	998.95	999.27	0.32

INTERVAL	XSEC	LOCN	EX. WS (ft)	PROP WS (ft)	DELTA (ft)
Q25	1254	d.se end of intake	993.89	995.85	1.96
Q25	1465	2/3 down intake	994.77	994.79	0.02
Q25	1600	1/3 down intake	1001.16	1001.27	0.11
Q25	1778	at diversion	1001.21	1001.31	0.1

At the time proposed modeling was performed, the Coanda screen was the preferred option. Since that time, the preferred screen type has changed to a vertical screen (shown in the 30% planset). The vertical screen option requires less screen bypass flow, and does not create the same backwater in the intake channel as the Coanda screen. The vertical screen option has not been modeled at this point and is not anticipated to have the same magnitude of impact on intake water surface elevations as the Coanda screen.

3.3.3 Floodplain

The White River at the project site is currently defined as a Zone A approximate floodplain, which has an approximate 100-yr boundary, but no detailed hydraulic study or published Base Flood Elevations (BFE's). Rio Blanco County is in the process of creating a detailed floodplain study within the project area that will establish a detailed floodplain, floodway, and base flood elevations (BFE). The process is likely a few years away from completion.

Due to the complexity of the proposed diversion, fish screen, and water delivery system, along with the relatively low floodplain elevations, and crude data used to extend cross-sections into the floodplain, more sophisticated three dimensional modeling along with collection of more detailed topographic information was recommended to the stakeholders in order to more fully understand operations. Rio Blanco County agreed to share detailed LIDAR aerial topography that has been collected in conjunction with the NFIP, and Alden Labs provided a cost estimate for performing three dimensional analysis.

3.3.4 Fish Passage and Entrainment

Of the species present in the upper White River basin, the CPW indicated that the Mountain Whitefish was taken to be the limiting species of concern used to inform the design of the fish passage. A naturalized vertical slot fishway is comprised of chambers separated by baffles. Within the baffle is a slot that extends the full height of the baffle. Fish move through the fish way by darting through the baffle slot from one chamber to the next. The hydraulics of a vertical slot fishway are engineered to create a non-turbulent resting place for fish. A channel bottom with embedded substrate would assist in the passage of smaller fish.

The total vertical distance from the invert of the intake channel to the invert at the exit of the return flow apron was found from survey to be 2.25 feet. Using this information, it was determined that five drops would be adequate for passage. Each chamber has a 1' wide slot and chambers are approximately 10' long (see **Exhibit E**).

With regards to fish entrainment, OneFish produced a 30% Fish Screen Design Report that can be found in the **Exhibit G**. Design of the fish screen went through several iterations as the design of the project progressed. The initial concepts focused upon use of a Coanda screen due to its anticipated cost, simplicity and function. As design progressed and associated hydraulics were analyzed, it became evident that the Coanda screen would not be simple nor significantly less money to build due to the unique nature of the Highland Ditch diversion. Hence, alternate methods were explored and a vertical fish screen located downstream in the ditch is preferred screen.

3.3.5 Scour Potential Analysis

Detailed scour analysis has not been performed. Experience provides estimates for scour potential associated with projects such as this. For estimating purposes, a minimum scour potential of three feet was used on all rock structures. The scour potential should be revisited and calculated in final design.

3.3.6 Sediment Transport Evaluation

Localized sediment aggradation and degradation does not appear to be an existing issue with the Highland Ditch. This condition is a reflection of the diversion's location and operation. Introduction of a permanent diversion would likely encourage upstream sediment aggradation, hence introduction of a sediment sluice or other sediment passing approaches should be incorporated into the design of any future diversion dam. As for the vertical fish screen and fish ladder, suspended sediments should be able to pass through both with minimal deposition. Sediment associated with bedload that are smaller than the vertical slot widths should be able to pass through the fish ladder in mobilizing flow events.

3.3.7 Debris Evaluation

Debris is a major factor on any stream and this is especially true on the White River in the region of the Highland Ditch. Several types of debris need to be accounted for at the project site including large debris, small debris, and algae. Large debris such as trees and drift wood will be of concern during high water. In order to prevent damage to the fish screen from large debris, it will need to be fitted with a trash rack. Additional cleaning for small debris and algae will be required for the vertical screens. This can be accomplished by installing an automated horizontal brush cleaner or periodic high pressure back flushing. It is also recommended that a small trash rack be installed at the upstream end of the fishway, to minimize the amount of debris entering the structure.

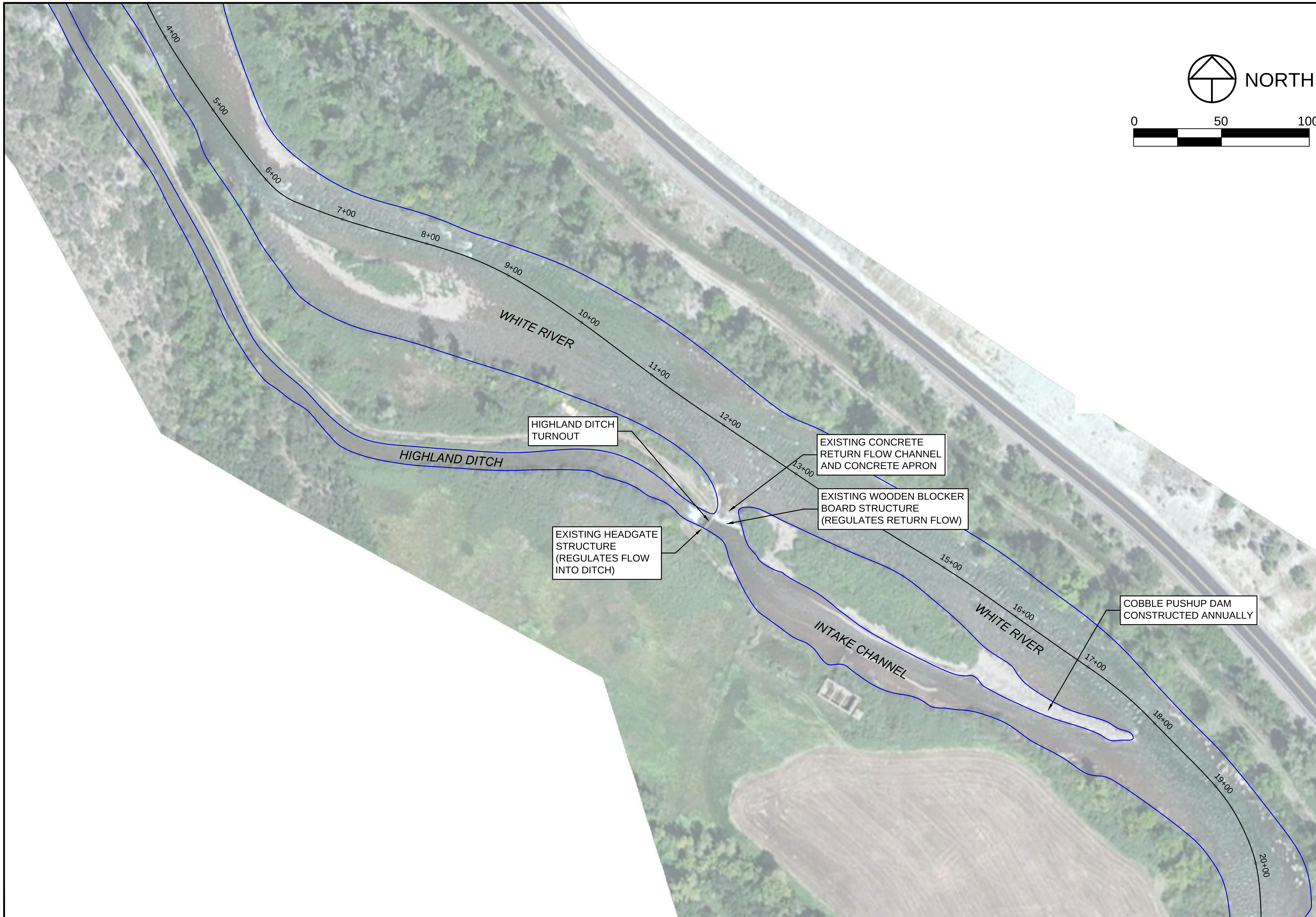
3.4 Permitting

The project is anticipated to be exempt from ACOE 404 permitting due to agriculture. It is premature to obtain a final opinion on this from ACOE at this point in design. Design should continue to focus upon optimum performance and cost as priorities over ACOE permitting. If an ACOE permit is required, it is believed that one could obtained without significant effort due to the positive ecological nature of the project.

Floodplain coordination with Rio Blanco County should continue as the project progresses. Rio Blanco County is in the process of entering into FEMA's National Flood Insurance Program (NFIP). Floodplain coordination and or permitting will be dependent upon the project's completion schedule.

At this time there are no foreseen water rights permitting actions associated with the project, although general coordination and documentation should be performed as the project progresses.

EXHIBITS



P.O. BOX 973
Fort Collins, CO 80522
www.flywater.com

HIGHLAND DITCH DIVERSION
EXISTING CONDITIONS

HIGHLAND DITCH DIVERSION
RIO BLANCO COUNTY, CO

EXHIBIT A
PL. SCALE: 1"=100'
DATE: Oct. 2015

Y:\FlyWater Projects and Promo\116-106 CWT Highland Ditch\Data_General\CAD\HighlandDitch111615.dwg 11/17/2015

Exhibit B

Highland Ditch Fish Salvage Program

Summary of 2012 to 2015 Results

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Executive Summary:

As part of a long-term, cooperative effort between the Highland Ditch Company, Colorado Parks and Wildlife (CPW) and others, sections of the Highland Ditch were salvaged between 2012 and 2015. Five locations were sampled during each salvage event. Fish were collected from the ditch using backpack electrofishing equipment, dipnets and seines. From 2012 through 2015 overall salvage efforts yielded a total of 3,249 fish that were salvaged from the Highland Ditch and returned to the White River. Eleven different fish species were found entrained in the ditch, seven native species including: bluehead sucker, Colorado River cutthroat trout, flannelmouth sucker, mountain sucker, mottled sculpin, mountain whitefish, and speckled dace; as well as four non-native species including: brook trout, brown trout, cutthroat rainbow hybrid trout (cutbow), and rainbow trout. These eleven species represent all of the fish species which are prevalent in the upper White River basin suggesting no species based selection for entrainment in the ditch. Multiple age classes of all species were also salvaged from the ditch showing no size selection relative to the potential for entrainment. Fish salvaged from the ditch ranged in size from a 20mm (0.8 inch) mottled sculpin up to a 612mm (24.1 inch) and 2332g (5.1 pound) rainbow trout. Significant numbers of fish will continue to be entrained in the Highland Ditch without substantial headgate redesign, thus CPW initiated a long-term collaborative effort with multiple partners in order to attempt to resolve this issue on the White River.

Introduction:

As part of a long-term, cooperative effort between the Highland Ditch Company, Colorado Parks and Wildlife (CPW) and others, sections of the Highland Ditch were salvaged between 2012 and 2015 to remove entrained fish. The entire length of the Highland ditch system which totals approximately 8 miles in length was scouted by CPW staff for concentrations of fish prior to implementation of fish salvage efforts in 2012. In order to be efficient with the limited time and resources available from CPW, only five locations (Table 1) along the upper half of the Highland ditch were ultimately identified and selected for fish salvage efforts. While fish are known to occur throughout the entire 8 miles of the Highland Ditch system, it was not practical or efficient to conduct a fish salvage operation over such a large area. In addition, entrained fish tend to naturally distribute and concentrate themselves within irrigation ditches where they have the best conditions for survival. Thus, a good portion of the entrained fish can be salvaged by focusing efforts within key concentration areas (i.e., around bridges and other structures within the ditch where greater water depth and overhead cover are available).

CPW conducted multiple fish salvage efforts between 2012 and 2015 at the five identified locations within the Highland Ditch where fish tend to be consistently concentrated for efficient salvage operations (Table 1). Fish were collected from these five locations within the Highland ditch using backpack electro-fishing units, dipnets and seines. During salvage efforts, all fish species captured were identified, and most were measured to total length weighed to the nearest gram, when possible. Fish were not weighed and measured during the March, 2014, salvage operation as CPW did not have a full fishery crew available to conduct the operation on such short notice from the Highland Ditch Company. After being captured from the Highland Ditch, all fish captured during the various salvage operations were temporarily held in oxygenated fish tanks until they could be processed. After processing, all live fish captured during salvage efforts were returned to the White River. The only exception to that was in March, 2014, when the majority of the mountain whitefish that were collected from the Highland Ditch were filleted and donated to the Buford Community Center for their local fish fry fund raiser event. Great care was taken by CPW crews and volunteers during all salvage efforts when capturing and processing fish in order to minimize stress and handling mortality. Despite warm water temperatures during July salvage events and thus increased stress on fish during summer fish salvage efforts, overall immediate fish mortality associated with the salvage efforts was extremely low, likely less than 10%, during all salvage events.

CPW wants to extend special thanks to the Highland Ditch Company for their support of the fish salvage efforts, to the private landowners that provided access to the salvage locations, and to the many volunteers that donated their time and equipment which have made the fish salvage efforts a tremendous success from 2012-2015.

Results:

Combined Results (All Fish 2012-2015):

A total of 3,249 total fish have been salvaged from the Highland Ditch as a result of the various salvage operations coordinated by CPW from 2012-2015. In total, eleven fish species have been found entrained in the ditch, seven of which are native to the White River drainage (Table 3). The majority of these fish were mountain whitefish (n=2202, 68% of total catch), followed by mottled sculpin, rainbow trout, mountain sucker, brown trout, speckled dace, flannelmouth sucker, cutbow trout, cutthroat trout, bluehead sucker, and brook trout in terms of percent abundance (Table 3). Fish lengths ranged from 20mm (<1") up to 612mm (24"), while fish up to 2,332g (5.1 pounds) were captured (Tables 2 and 3; Figure 1).

Several different trout species were captured during salvage efforts. One hundred eighty Brown Trout were captured from the ditch and 304 Rainbow Trout were captured with trout up to 24" in length being salvaged. Overall across all trout species 494 trout were captured. Of those 494 trout, 168 (34%) were greater than 15" total length, 84 (17%) were greater than 18" total length, and 26 (5%) were greater than 20" total length (Figures 2 and 3). All age classes of mountain whitefish have been found entrained in the Highland Ditch with fish ranging from 2.4 to 21.3" (Figure 4).

The relative number of fish entrained within and subsequently salvaged from the Highland Ditch varied considerably from 2012-2015, primarily due to the variation between water years and flows in the White River. The annual variability in snowpack and the seasonal dynamics associated with water flows in the White River dictates the timing, duration and intensity of diversion practices that are necessary by the Highland Ditch Company (i.e., push-up dam) to meet their irrigation demands, which directly influences the susceptibility of fish to entrainment. It is important to note that 2012 was one of the worst drought years in recent history thus water flows in the White River were relatively low, diversion practices were intensive, and subsequently fish entrainment levels into the Highland Ditch were relatively high in 2012 as compared to more average or above average water years from 2013-2015. However, even though 2013-2015 were considered average to above average in terms of annual precipitation and snowpack levels, there were still certain periods during summer and early fall from 2013-2015 when water flows in the White River reached critically low levels for fish survival. Therefore, it is important to realize that even during "above average" water years on the White River, fish entrainment is still a significant issue within the Highland Ditch that needs to be resolved if possible.

<u>2012 Results:</u>

In 2012, a total of 1162 fish were salvaged from the Highland Ditch (Tables 2 and 3). The 1162 total fish were comprised of 651 mountain whitefish (55% of total catch), 164 mountain sucker (14%), 141 mottled sculpin (12%), 93 rainbow trout (8%), 68 brown trout (6%), 36 speckled dace (3%), 5 flannelmouth sucker (0.4%), 3 cutthroat rainbow hybrid (cutbow) trout (0.3%), and 1 cutthroat trout (0.1%) representing 9 species (6 native and 3 non-native). One hundred sixty five trout were salvaged in 2012 with 4 trout species present (brown, cutbow, cutthroat, and rainbow trout), representing 14% of total catch. Trout ranged from 60-611mm (2-24") with 80 trout > 361mm (>15"), 46 trout > 457mm (>18"), and 10 trout > 508mm (>20") (Figure 3).

<u>2013 Results:</u>

In 2013, 930 total fish were salvaged between two sampling events (Tables 2 and 4). Ten species (6 native and 4 non-native) were collected with 747 mountain whitefish (80% of total catch), 63 rainbow trout (7%), 50 mottled sculpin (5%), 33 brown trout (4%), 24 mountain sucker (3%), 6 flannelmouth sucker (0.6%), 3 bluehead sucker (0.3%), 2 cutthroat trout (0.2%), 1 cutbow trout (0.2%), and 1 brook trout (0.2%). One hundred trout were salvaged in 2013 with 5 trout species present (brown, brook, cutbow, cutthroat, and rainbow trout), representing 11% of total catch. Trout lengths ranged from 125-612mm (5-24") with 39 trout > 361mm (>15"), 13 trout > 457mm (>18"), and 4 trout > 508mm (>20") (Figure 3). Figure 4 shows results from a relative weight (Wr) analysis of all trout with length and weight data for 2013 which showed that 51% of trout had Wr values < 93 while 49% of trout had Wr scores ≥ 93 (a relative weight value of 93 represents the average condition of an average fish). Relative weight scores ranged from 49-128 with an average of 92.

2014 Results:

In 2014, at least 537 total fish were salvaged between three sampling events, March 29-30, July 8, and November 25. Lengths and weights were not taken on the fish salvaged during the March, 2014 operation (only total number of fish by species), due to the small crew of volunteers that were available on such short notice for that particular salvage operation. In addition, part of the July fish salvage data was lost due to a misplaced datasheet; however, conservative numbers were calculated for number of fish salvaged in July of 2014 of 28. It was likely that around 50 total fish were salvaged in July, 2014 so overall estimates for 2014 are likely low. Only four species were captured in the ditch during 2014 salvage operations including: brown trout, mountain whitefish, rainbow trout, and cutbow trout. Overall species composition of entrained fish in 2014 was dominated by mountain whitefish, representing 88% of total catch.

2015 Results:

In 2015, a total of 627 fish were salvaged in a single effort on November 17. All fish salvaged belonged to one of six species: mottled sculpin, speckled dace, mountain sucker, brown trout, rainbow trout, and mountain whitefish. Four out of six of these species are native to the White River system, mottled sculpin, speckled dace, and mountain sucker. The most abundant species salvaged was the mountain whitefish (n= 339) at 54% of the catch, followed by mottled sculpin (n=115) at 18.3% of the catch. The remainder of the fish salvaged included rainbow trout (n=103) 16.4%, brown trout (n=61) 9.7%, mountain sucker (n=6) 1% and speckled dace (n=3) 0.5%. The combined catch for both trout species was 164 fish, which compares favorably with previous salvage efforts. Multiple age classes were present in both trout species captured. The smallest rainbow trout captured was 3.6 inches, the largest was 20.5 inches and the mean length was 8.0 inches. The smallest brown trout was 3.5 inches, the largest was 23.6 inches and the mean length was 9.2 inches.

Discussion:

Overall, fish salvage results from the Highland Ditch between 2012 and 2015 show significant annual entrainment of fish that, if not for the cooperative salvage efforts, would otherwise have been mortalities and a corresponding loss of local White River fishery resources. A total of 3,249 fish were salvaged by CPW staff and volunteers from the Highland Ditch between 2012 and 2015 (Table 3). Eleven species of fish (7 native and 4 non-native) have been salvaged from the Highland Ditch which represents all of the prevalent species within the upper White River drainage (Table 3 and Figure 1). The presence of these eleven fish species entrained in the

Highland Ditch suggests no species bias in terms of potential for or susceptibility to entrainment. Additionally, multiple age classes of most fish species have been found entrained in the Highland Ditch showing no size selection relative to the potential for or susceptibility to entrainment.

Overall salvaged fish ranged in size from a 20mm (0.8 inch) mottled sculpin up to a 612mm (24.1 inch) and 2332g (5.1 pound) rainbow trout. Despite this range in size, over 93% of all fish captured in the Highland Ditch were greater than 100mm (~4 inches). However, this is not to suggest that small bodied and juvenile fish are not being entrained in the ditch. Sampling bias from gear types, netting preference, and sampling site selection all likely lead to larger fish being captured more readily than small fish, but was not necessarily representative of true numbers and composition of fish entrained in the ditch. For example, only five short sections of the Highland Ditch were salvaged on an annual basis because those areas represented the best holding habitat for larger fish yet small bodied fish, such as mottled sculpin, that can survive in shallower water and prefer different habitat types were likely abundant across the 8 miles of the Highland Ditch and were not properly represented in fish salvage data. In addition, it is likely that many of the smaller age-classes of fish were predated upon heavily by larger fish within the areas where major concentrations of fish occurred within the Highland Ditch, which further biases the salvage data results in terms of relative proportions of age-classes and sizes of fish that are entrained. Results from this report were designed to provide a baseline to document entrainment levels and represent a very conservative estimate in every regard for fish entrainment.

Salvage data from 2012-2015 suggests significant variability in entrainment levels across years, which is to be expected based on the relationship between overall annual discharge in the White River, seasonal flow dynamics during the irrigation season, proportion of river flow diverted and extent/timing of push-up dam, and ultimately the potential for and susceptibility of fish to entrainment from the White River into the Highland Ditch. This variability in fish entrainment was likely driven by overall annual water discharge and dynamics of seasonal flow conditions in the White River from 2012-2015. During below average water years and droughts (2012) and also during above average water years when summer flows were not maintained (2013) the Highland Ditch was forced to utilize the push-up dam to the fullest extent and divert a substantial proportion of White River flow in order to meet their irrigation demands, thus fish entrainment issues were likely exacerbated in those types of water year scenarios. However, during average or above average water years like 2014 in particular when flows in the White River remained relatively high throughout most of the summer, the Highland Ditch only had to utilize the push-up dam as needed and diverted a smaller proportion of overall flows from the White River for irrigation needs and thus fish entrainment levels in 2014 were substantially lower.

Entrainment and losses of all species and sizes of fish in any irrigation diversion has negative implications on the overall health and sustainability of the fishery resources in the White River drainage. The Highland Ditch just happens to be one of the largest irrigation diversions on the White River, but it is certainly not the only diversion that is negatively impacting the fishery resources due to fish entrainment issues. Hopefully, the collaborative effort with the Highland Ditch Company will be successful and will serve as a pro-active and cooperative model for other ditch companies and diversions on the White River and beyond. Native fish species such as mountain whitefish, mountain sucker, bluehead sucker, flannelmouth sucker, mottled sculpin, and speckled dace are all vital to the sustainability and ecological integrity of the aquatic ecosystem. The ecological importance and roles of these native fish species are imperative in maintaining proper function and health of the White River. It is very likely that the native mountain whitefish and native suckers that are currently found in the upper White River and in other areas of Colorado will eventually be listed as either threatened or endangered by the U.S. Fish and Wildlife Service at some point in the future, which could obviously have huge implications to how irrigation diversions are designed and operated. Therefore, pro-active and collaborative efforts such as this one on the Highland Ditch to voluntarily and cooperatively resolve fish entrainment issues could potentially be very important in the future.

In addition, trout entrained in the Highland Ditch are top predators in the aquatic ecosystem and are also an integral part to the overall health and ecological diversity of the White River. Trout and mountain whitefish are also desirable recreational sportfish in the White River which provide tremendously important economic value to the local community and to the entire state of Colorado. The overall quality of trout and whitefish being entrained in the Highland Ditch has also been of significance which represents even greater loss to the local fishery resource and economy. Several of the larger trout and whitefish that were salvaged from the Highland Ditch would have qualified for a Master Angler award: including 2 brown trout, 2 rainbow trout, and 309 mountain whitefish. It is important to note that three of the largest mountain whitefish salvaged from the Highland Ditch would have broken the current Colorado state record for Mountain Whitefish in terms of length, but not weight.

Fish entrainment in the Highland Ditch has remained steady from 2012-2015 and continues to represent a substantial threat to the White River fishery. CPW's current efforts to periodically salvage fish from the Highland Ditch have been relatively successful at mitigating the loss, but these represent a substantial commitment of resources and CPW realizes that only a portion of the total fish that are actually entrained annually have been salvaged due to the relatively small and limited scale of the salvage efforts. There is no doubt that the total numbers of fish salvaged annually from the 5 limited salvage sites at the upper end of the Highland Ditch system are very conservative and low estimates of the total number of fish that are actually entrained in the entire Highland Ditch system annually. While the salvage efforts have been an excellent example of cooperative resource management, a long-term solution is desired which will more effectively eliminate the impact that entrainment in the ditch has on the fishery resource. Various fish screening options exist that can virtually eliminate entrainment of fish from the White River into the Highland Ditch, but each design has its own suite of pros and cons which must be carefully evaluated by all stakeholders. The continued cooperation of all stakeholders, the community, and resource managers to design and implement upgrades to the Highland Ditch diversion structure and others can help to ensure the productivity and sustainability of the aquatic fishery resources in the White River for generations to come.

Recommendations:

1. Continue annual fish salvage efforts in cooperation with the Highland Ditch Company and various private landowners in order to document entrainment rates during different water years.

2. Continue to promote long-term efforts with the Highland Ditch Company and other stakeholders to cooperatively and collaboratively re-design existing irrigation diversion and headgate systems on the White River in order to minimize overall potential for entrainment of fish.

Acknowledgements:

CPW would like to acknowledge the help and support of the many parties that have helped make the Highland Ditch fish salvage efforts a success from 2012-2015. The Highland Ditch Company and multiple private landowners have granted CPW permission to access key areas along the Highland Ditch where fish salvage operations have occurred each year. CPW also acknowledges Elk Creek Ranch who has graciously provided volunteer labor and specialized OHV fish transporting resources to CPW from 2012-2015 which have been instrumental in the success of the annual fish salvage efforts. CPW also thanks Trout Unlimited for providing volunteer labor to salvage efforts. In addition, many local youth groups (4-H club and Barone Middle School) have actively participated on all fish salvage efforts as volunteers through CPW’s educational outreach programs which is greatly appreciated.

Table 1: Five primary Highland Ditch sampling stations selected for fish salvage operations.

Sampling Station	Zone	Easting	Northing
Station 1: HD Headgate	13S	259812	4429139
Station 2: Overhanging Tree	13S	259633	4429259
Station 3: HD Flume	13S	259427	4429509
Station 4: Issac's Bridge	13S	258454	4430429
Station 5: Roger's/TI Bridge	13S	256667	4433193

Table 2: Highland Ditch sampling events and fish captures for each salvage effort.

Sampling Event	Total Fish Salvaged
7/13/2012	375
11/30/2012	787
7/11/2013	397
11/26/2013	533
3/29/2014	480
7/8/2014*	28*
11/25/2014	22
11/25/2015	627
Total	3249

*Datasheets were lost from this sampling event, but these are conservative estimates based on data that was retained. Actual numbers were likely around 50 total fish.

Table 3: 2012-2015 Highland Ditch catch by species. * Distinguish species native to the White River drainage.

Species	**Number Caught**	**Percent Composition**	**Mean Length**	**Min Length**	**Max Length**
*Bluehead Sucker	3	0.09	17.56	16.81	18.31
Brook Trout	1	0.03	12.80	12.80	12.80
*Cutthroat Trout	3	0.09	12.23	8.86	14.57
*Flannelmouth Sucker	11	0.34	18.93	17.36	21.89
Brown Trout	180	5.54	10.21	2.36	23.62
*Mountain Sucker	194	5.97	6.20	1.57	13.78
*Mottled Sclupin	306	9.42	3.27	0.79	6.02
*Mountain Whitefish	2202	67.77	12.77	2.40	24.61
Rainbow Trout	304	9.36	11.83	3.23	24.09
Cutbow Trout	6	0.18	15.33	11.61	18.58
*Speckled Dace	39	1.20	2.07	0.98	3.39
Total	**3249**				

Figure 1: 2012-2015 Highland Ditch species composition of all fish captured.

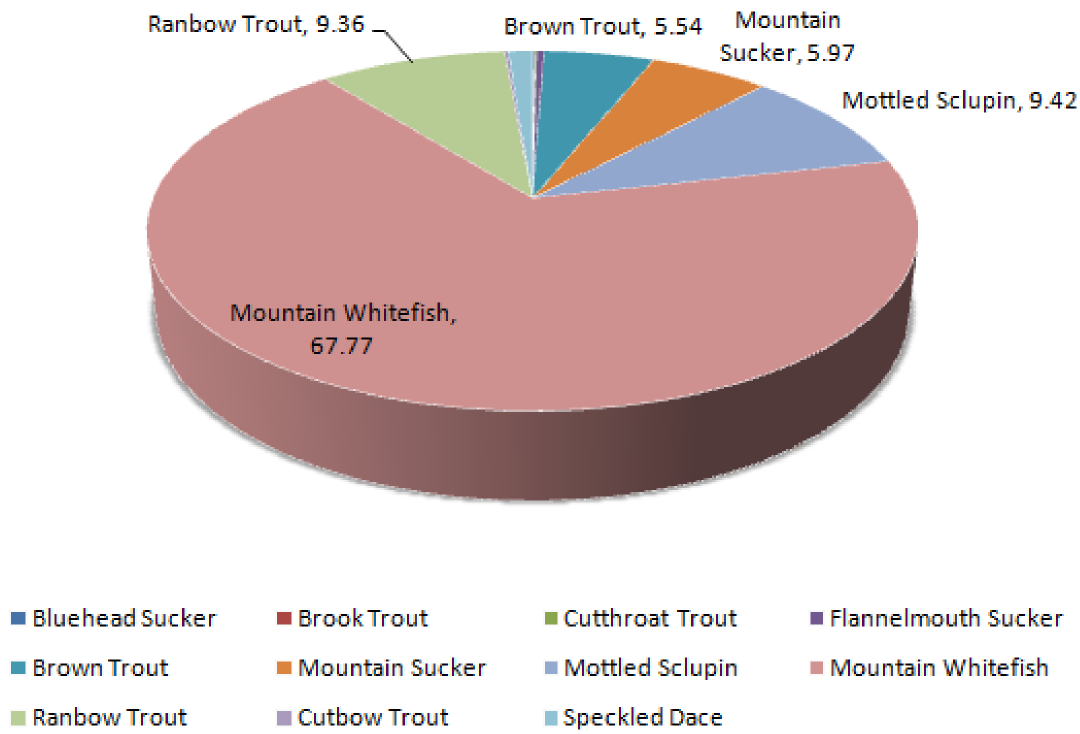


Figure 2: Length Frequency histogram of all Brown Trout with length data captured in the Highland Ditch.

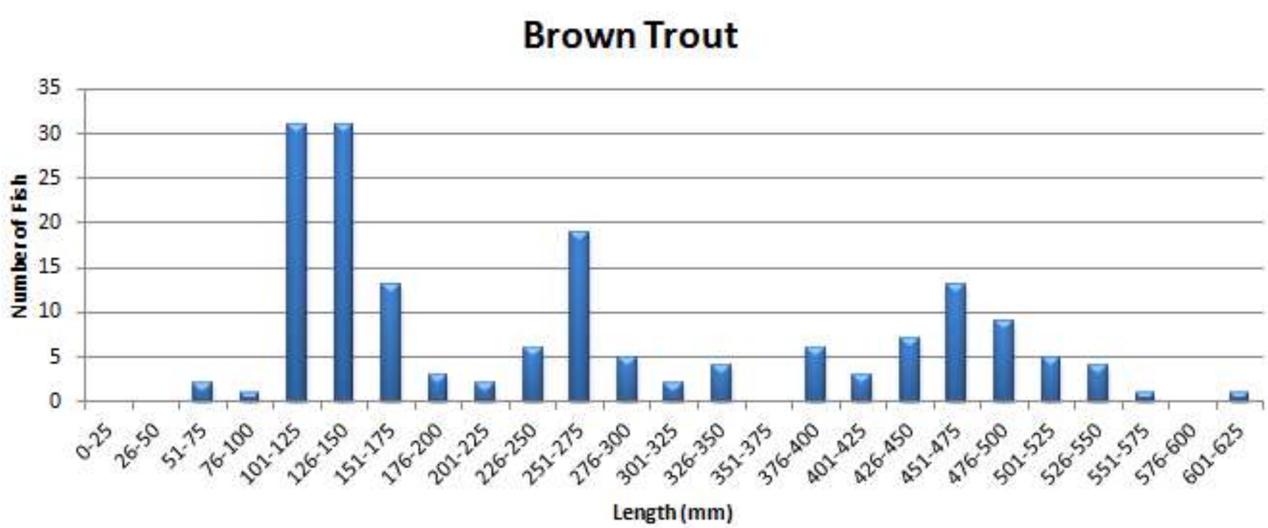


Figure 3: Length Frequency histogram of all Rainbow Trout with length data captured in the Highland Ditch.

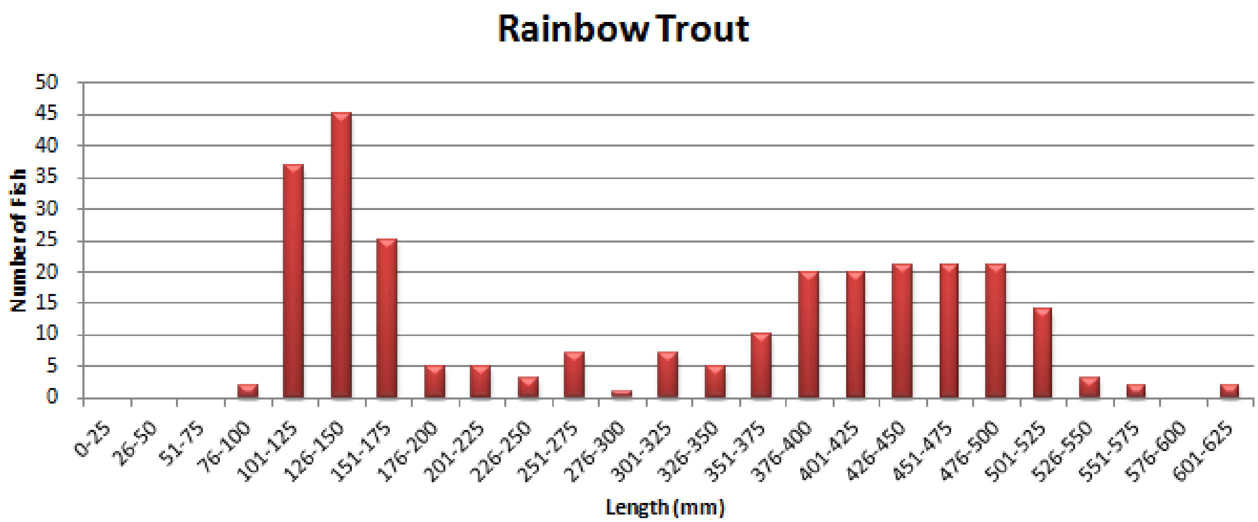
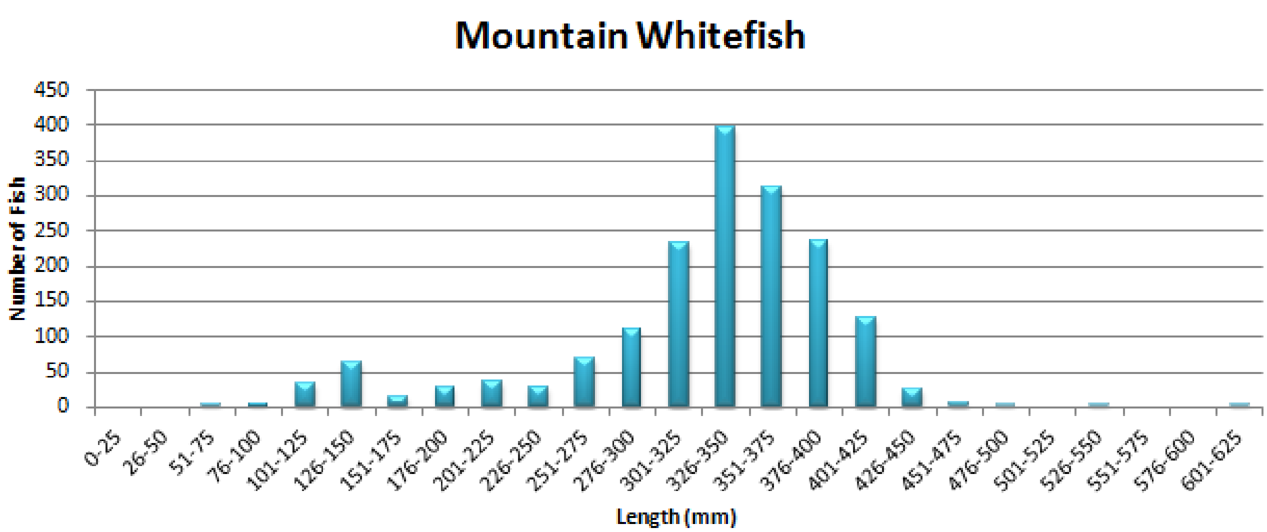


Figure 4: Length Frequency histogram of all Mountain Whitefish with length data captured in the Highland Ditch.



Appendix

Figure 6: Existing headgate structure at beginning of Highland Ditch.

Figure 7: District Wildlife Manager Evan Jones and an Elk Creek Ranch Guide use backpack electrofishing units to salvage fish from the Highland Ditch.

Figure 8: Aquatic Biologist Kyle Battige and a local 4H student with a salvaged rainbow trout.

Figure 9: District Wildlife Manager Terry Wygant with a native flannelmouth sucker salvaged from the Highland Ditch.

Figure 10: District Wildlife Manager Bailey Franklin and local youth (Melanie Wangnild) release a 22” rainbow trout salvaged from the Highland Ditch back into the White River.

Figure 11: Local youth (CJ Wangnild) releases a native flannelmouth sucker salvaged from the Highland Ditch back into the White River.

Figure 12: A 23” rainbow trout salvaged from the Highland Ditch.

Figure 13: A 19” brown trout salvaged from the Highland Ditch.

Figure 14: Colorado Parks and Wildlife fishery technicians and local 4-H youth take length and weight data on native mountain whitefish salvaged from the Highland Ditch.

Figure 15: Meeker middle school students, Tatum Kennedy and Emily Amick, collect data and pose with a large native mountain whitefish salvaged from the Highland Ditch.

Figure 16: Meeker middle school teacher Teresa Anderson and student Kelton Turner, collect data on a large brown trout salvaged from the Highland Ditch.

Figure 17: Meeker middle school students collect data and Aspen Merrifield poses with a large rainbow trout salvaged from the Highland Ditch.

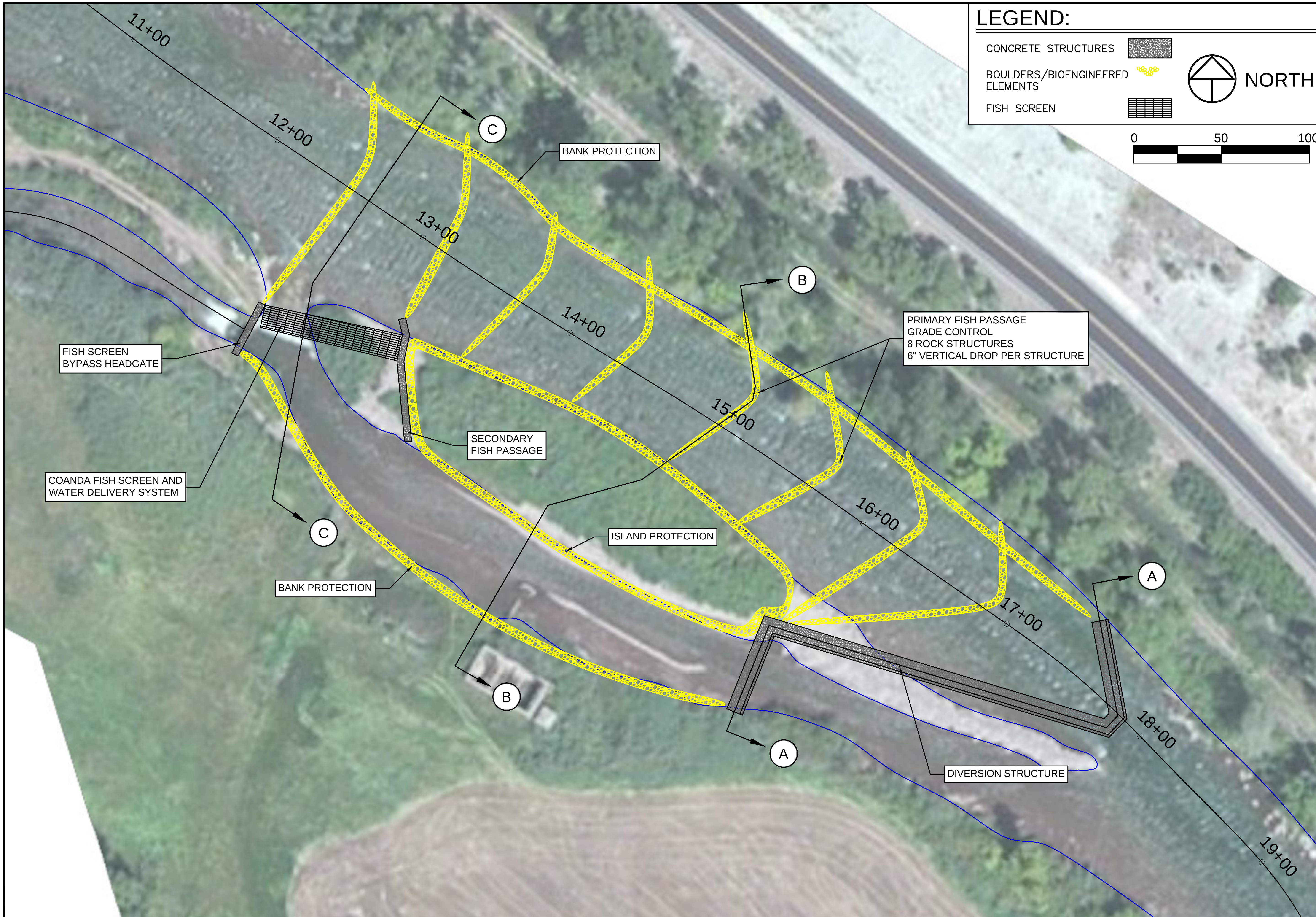
Figure 18: Colorado Parks and Wildlife Commissioner Jeanne Horne working the seine and Montey Franklin netting fish from the Highland Ditch.

Figure 19: Franklin family, Wildlife Commissioner Jeanne Horne and volunteer Mark Scritchfield netting fish from the Highland Ditch.

Figure 20: Montey Franklin and little brother Miles Franklin releasing a brown trout back into the White River after being salvaged from the Highland Ditch.

Figure 21: Miles Franklin transferring fish from holding tank at fish salvage event.

Figure 22: Hadley Franklin preparing to release native mountain whitefish back into the White River after being salvaged from the Highland Ditch.



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HIGHLAND DITCH DIVERSION
MODIFICATION PROJECT (HDDMP)
PRELIMINARY DESIGN ITERATION 1

HIGHLAND DITCH DIVERSION

RIO BLANCO COUNTY, CO

EXHIBIT C1

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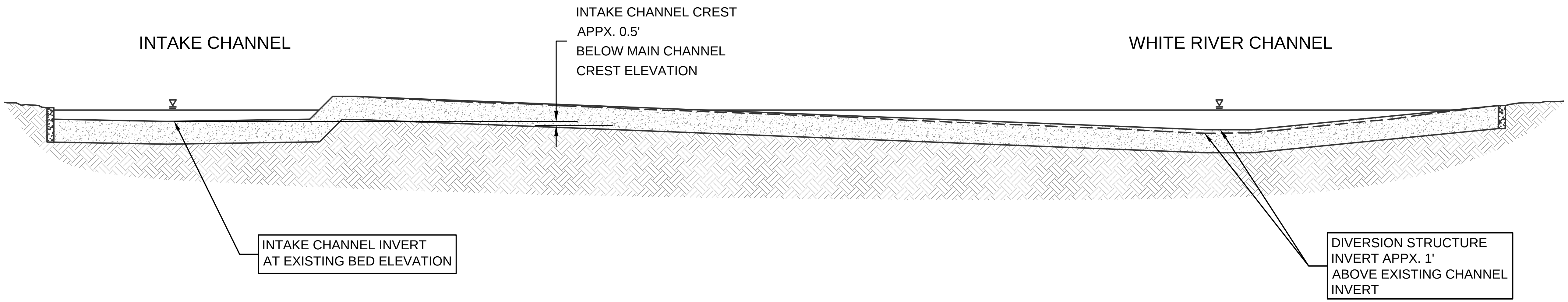

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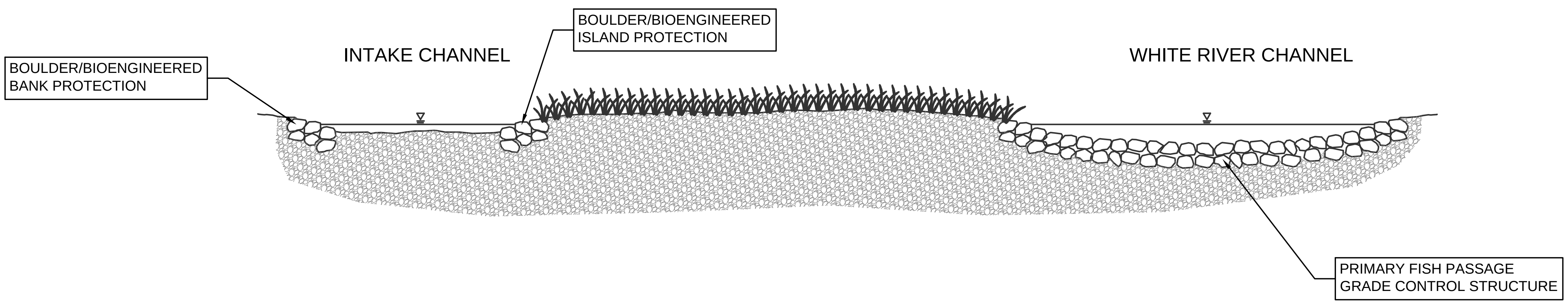

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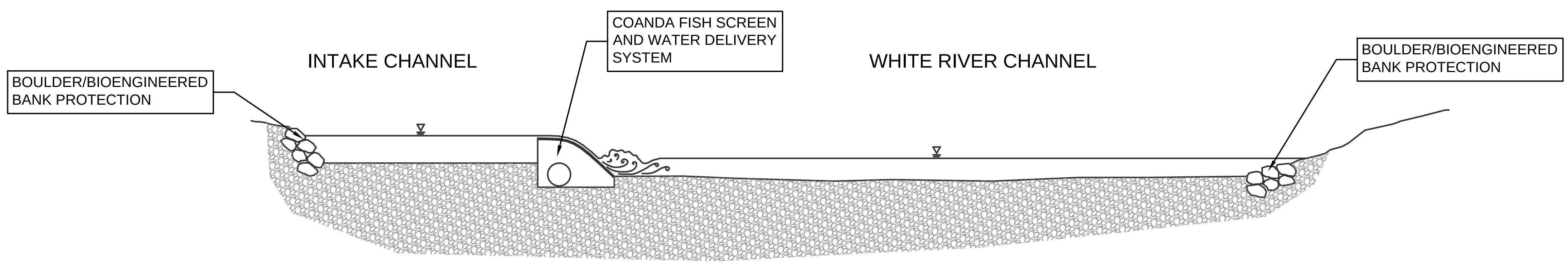

SECTION C-C

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HIGHLAND DITCH DIVERSION
MODIFICATION PROJECT (HDDMP)
PRELIMINARY DESIGN ITERATION 1

HIGHLAND DITCH DIVERSION

RIO BLANCO COUNTY, CO

EXHIBIT C2

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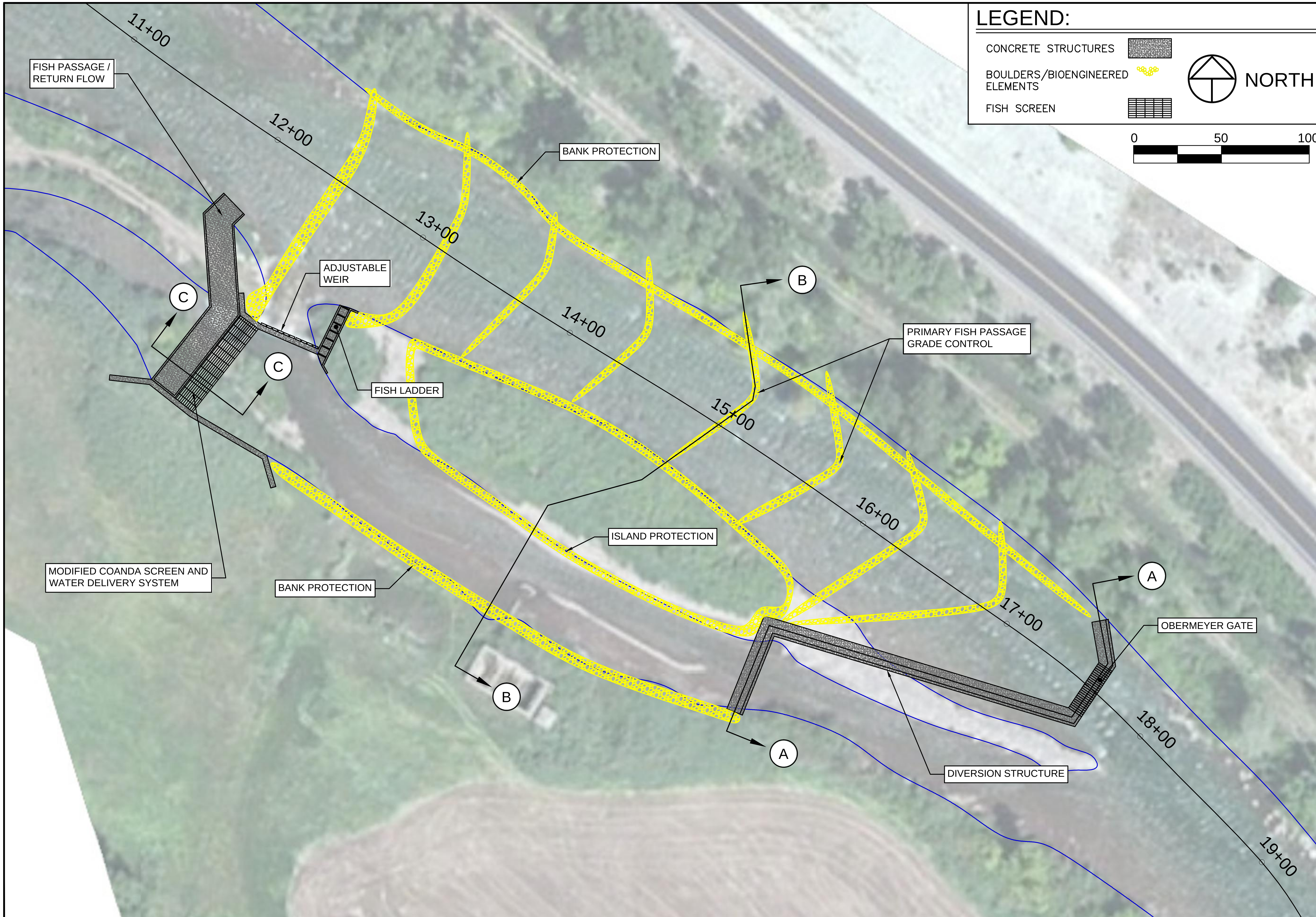

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HIGHLAND DITCH DIVERSION
MODIFICATION PROJECT (HDDMP)
PRELIMINARY DESIGN ITERATION 2

HIGHLAND DITCH DIVERSION

RIO BLANCO COUNTY, CO

EXHIBIT D1

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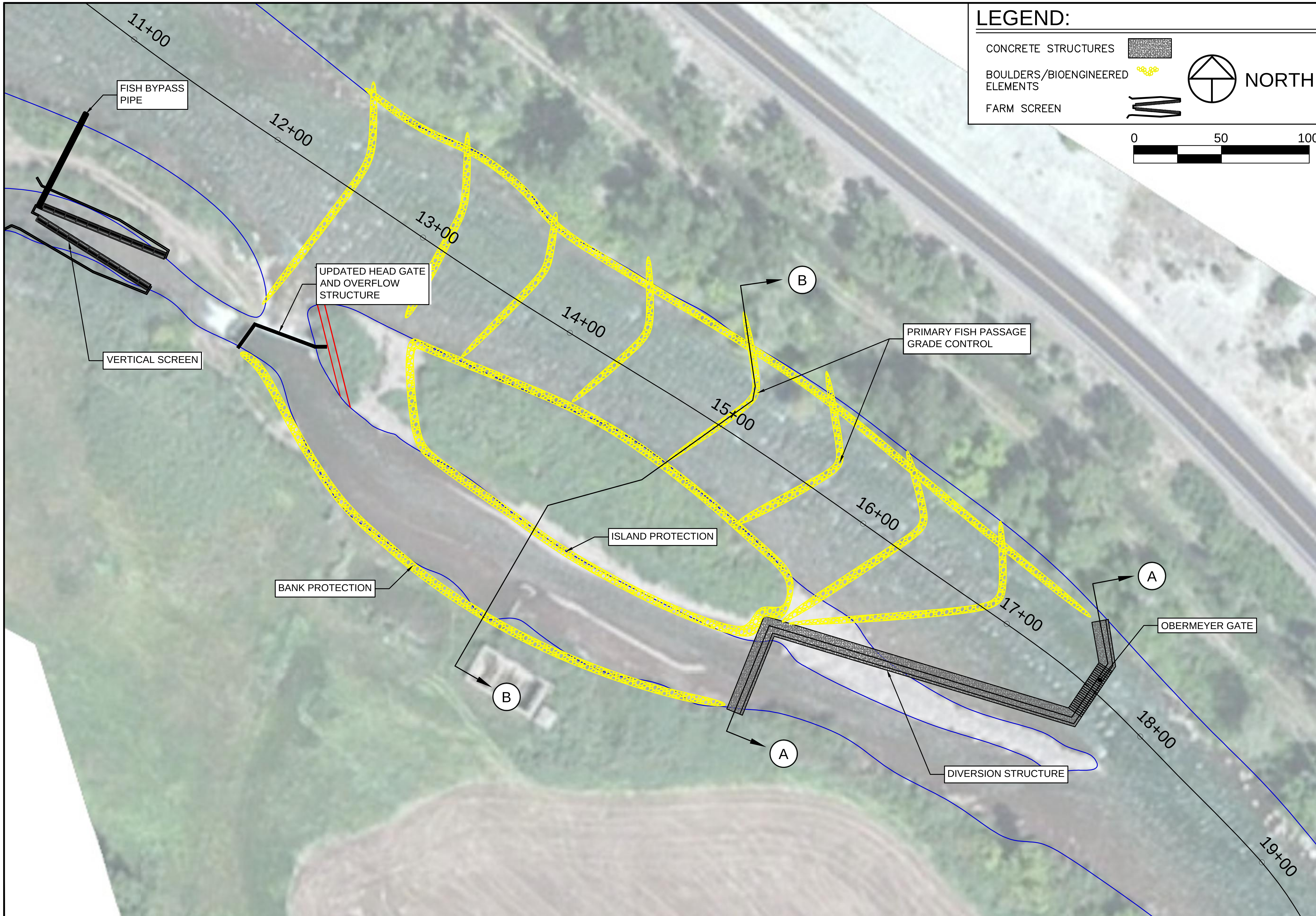

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HIGHLAND DITCH DIVERSION
MODIFICATION PROJECT (HDDMP)
PRELIMINARY DESIGN ITERATION 2

HIGHLAND DITCH DIVERSION
RIO BLANCO COUNTY, CO

EXHIBIT D2
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DATE: Jun. 2015

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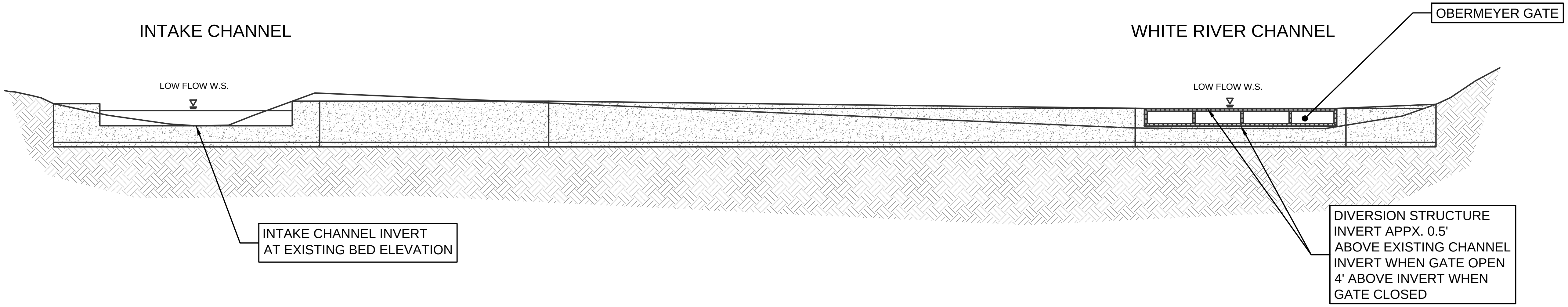

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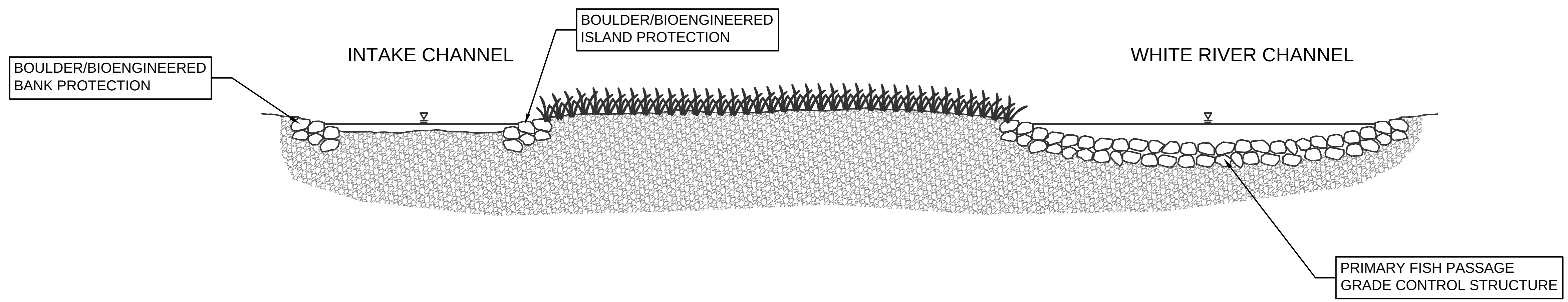

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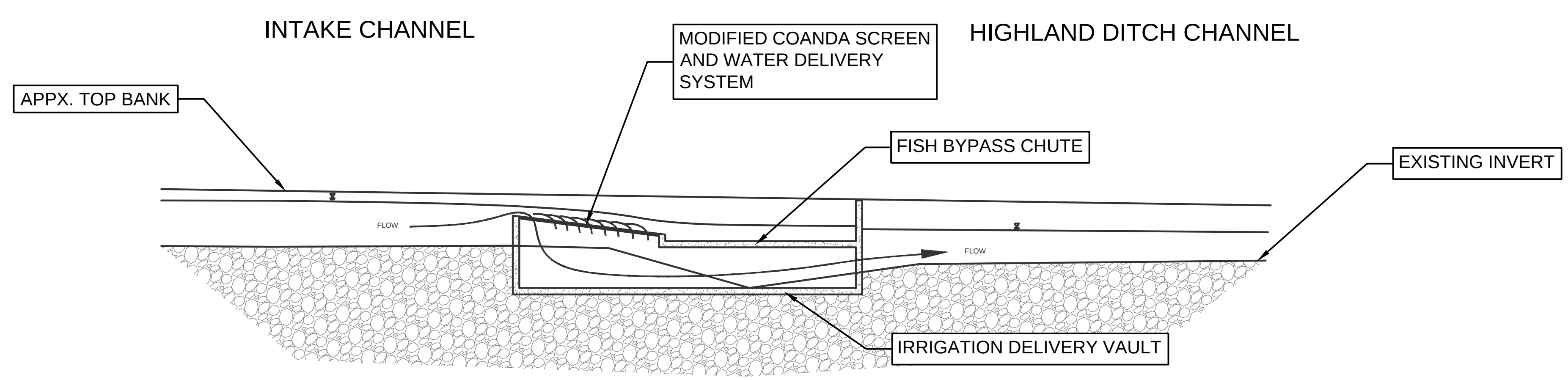

SECTION C-C

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PRELIMINARY DESIGN ITERATION 2

HIGHLAND DITCH DIVERSION

RIO BLANCO COUNTY, CO

EXHIBIT D3

SCALE : N.T.S.
DATE: Jun. 2015

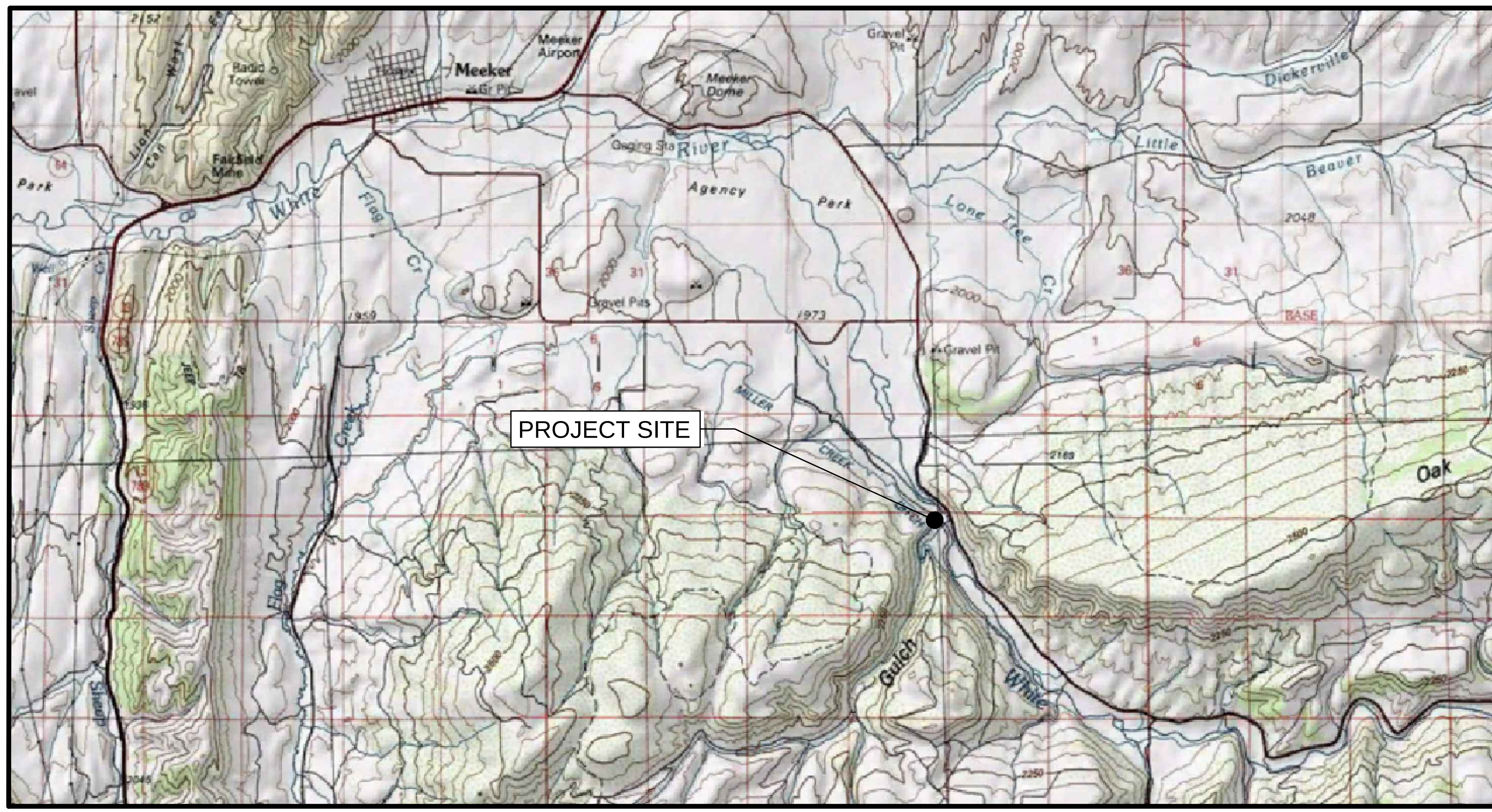
HIGHLAND DITCH DIVERSION IMPROVEMENT PROJECT

RIO BLANCO, COLORADO

DESIGN ITERATION 3 (PREFERRED DESIGN)

OWNER : Colorado Water Trust
DESIGN : FlyWater, inc.,
OneFish Engineering LLC

SHEET INDEX



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PRELIMINARY DESIGN ITERATION 3
PREFERRED DESIGN

HIGHLAND DITCH DIVERSION
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EXHIBIT E1
JUL. 2015

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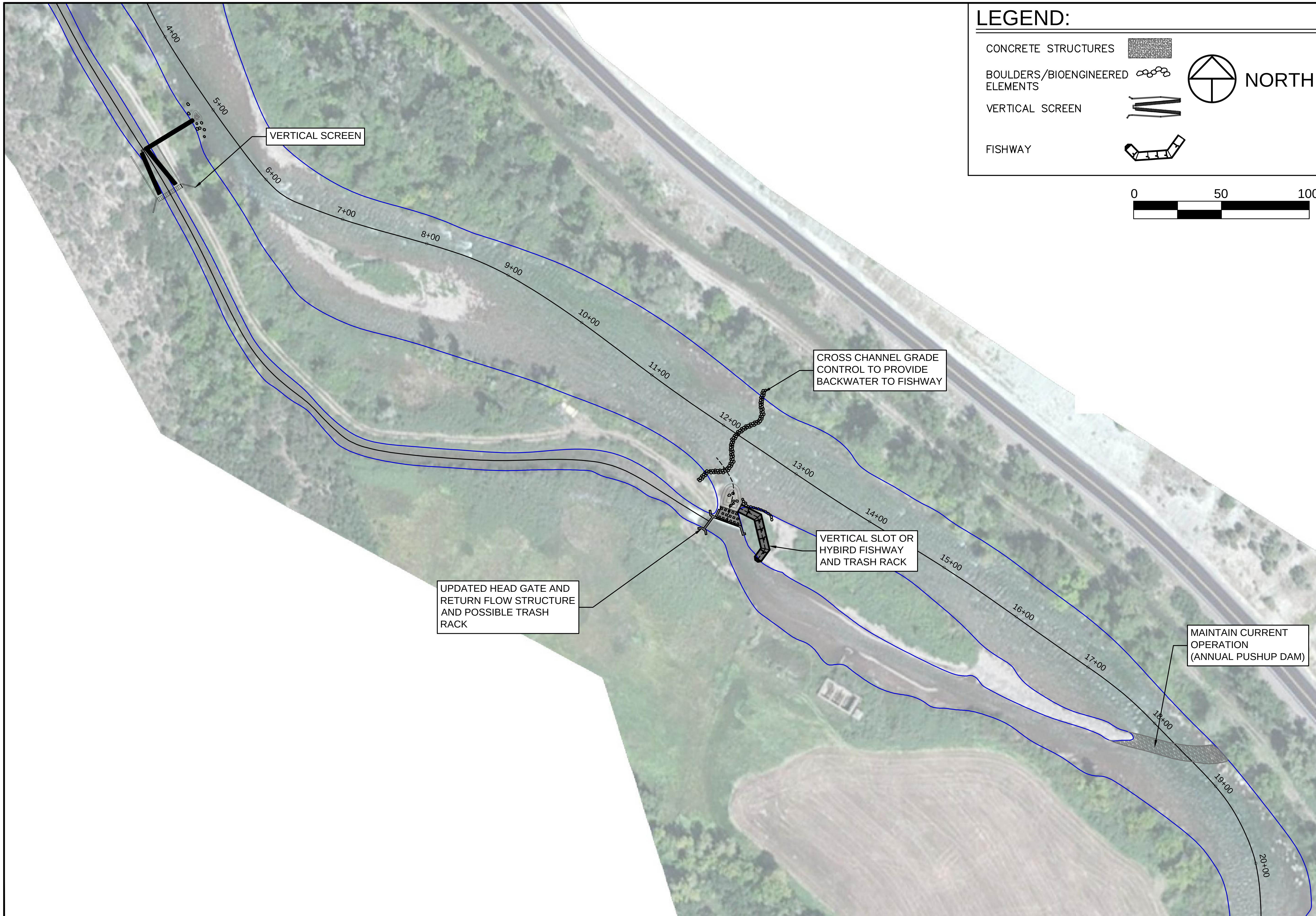

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MODIFICATION PROJECT (HDDMP)
PRELIMINARY DESIGN ITERATION 3
PREFERRED DESIGN

HIGHLAND DITCH DIVERSION

RIO BLANCO COUNTY, CO

EXHIBIT E2

PL. SCALE: 1"=100'
DATE: Oct. 2015

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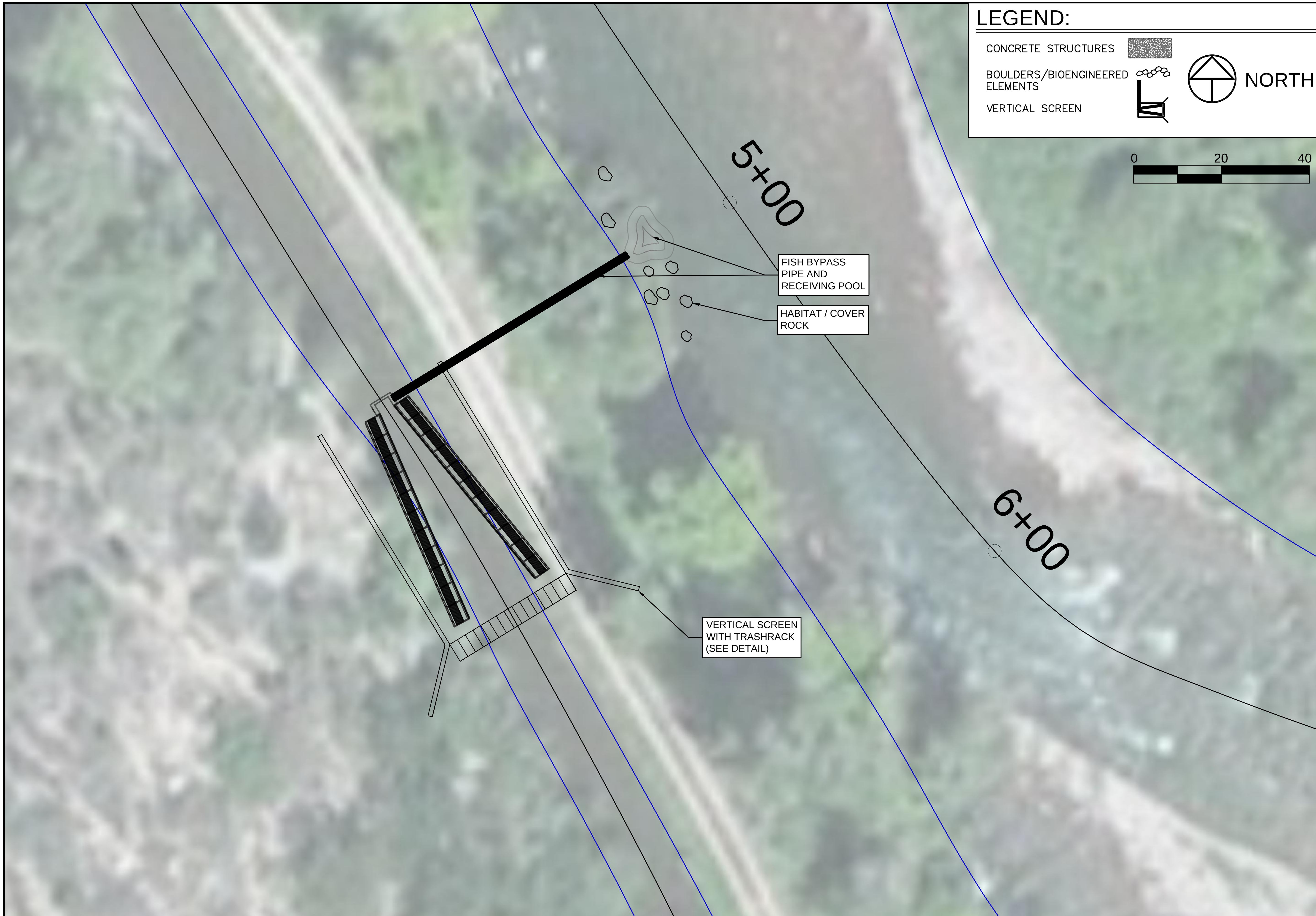

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HIGHLAND DITCH DIVERSION
MODIFICATION PROJECT (HDDMP)
PRELIMINARY DESIGN ITERATION 3
PREFERRED DESIGN (VERTICAL PLATE SCREEN)

HIGHLAND DITCH DIVERSION

RIO BLANCO COUNTY, CO

EXHIBIT E3

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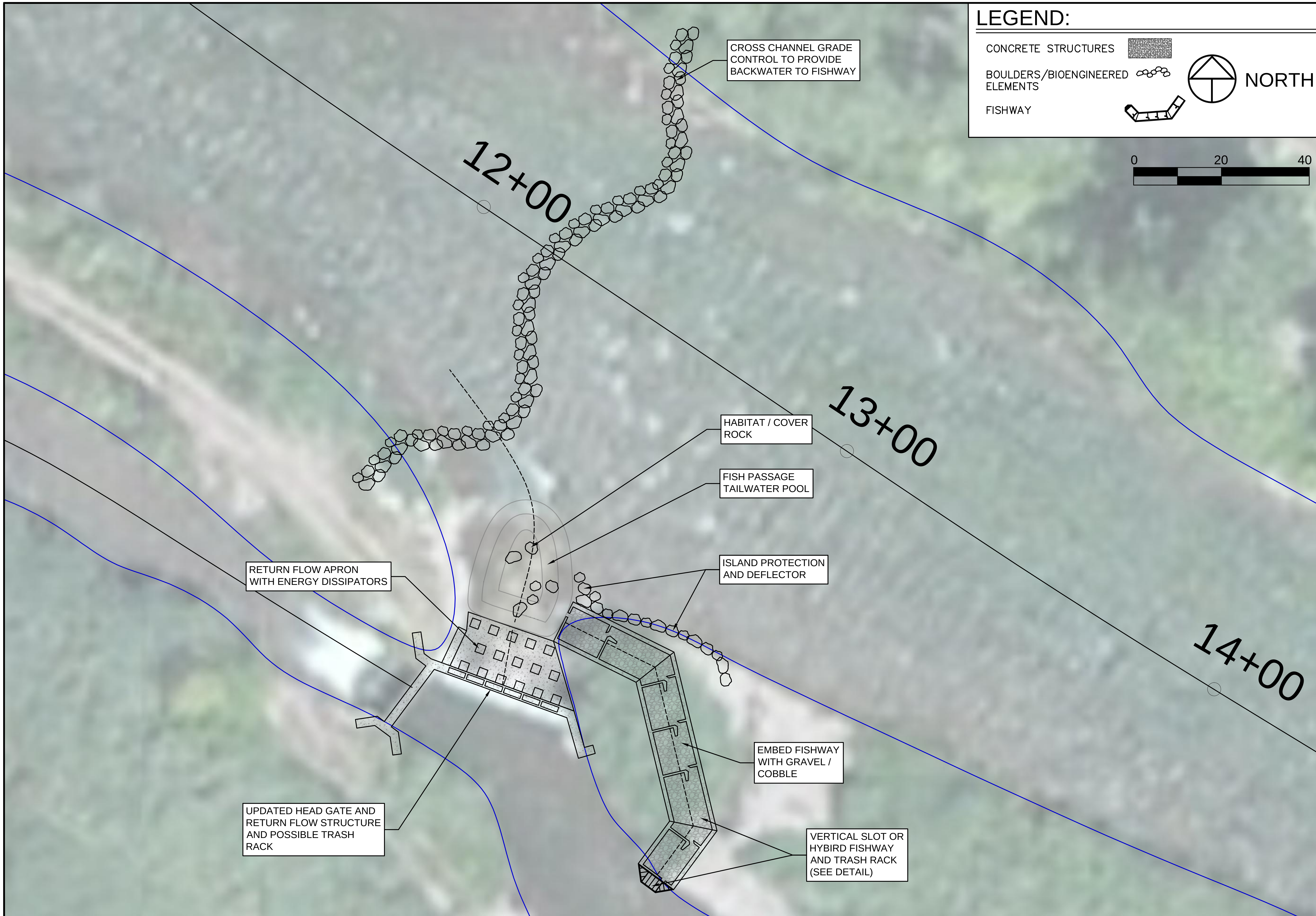

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HIGHLAND DITCH DIVERSION
MODIFICATION PROJECT (HDDMP)
PRELIMINARY DESIGN ITERATION 3
PREFERRED DESIGN (HEADGATE / FISHWAY)

HIGHLAND DITCH DIVERSION

RIO BLANCO COUNTY, CO

EXHIBIT E4

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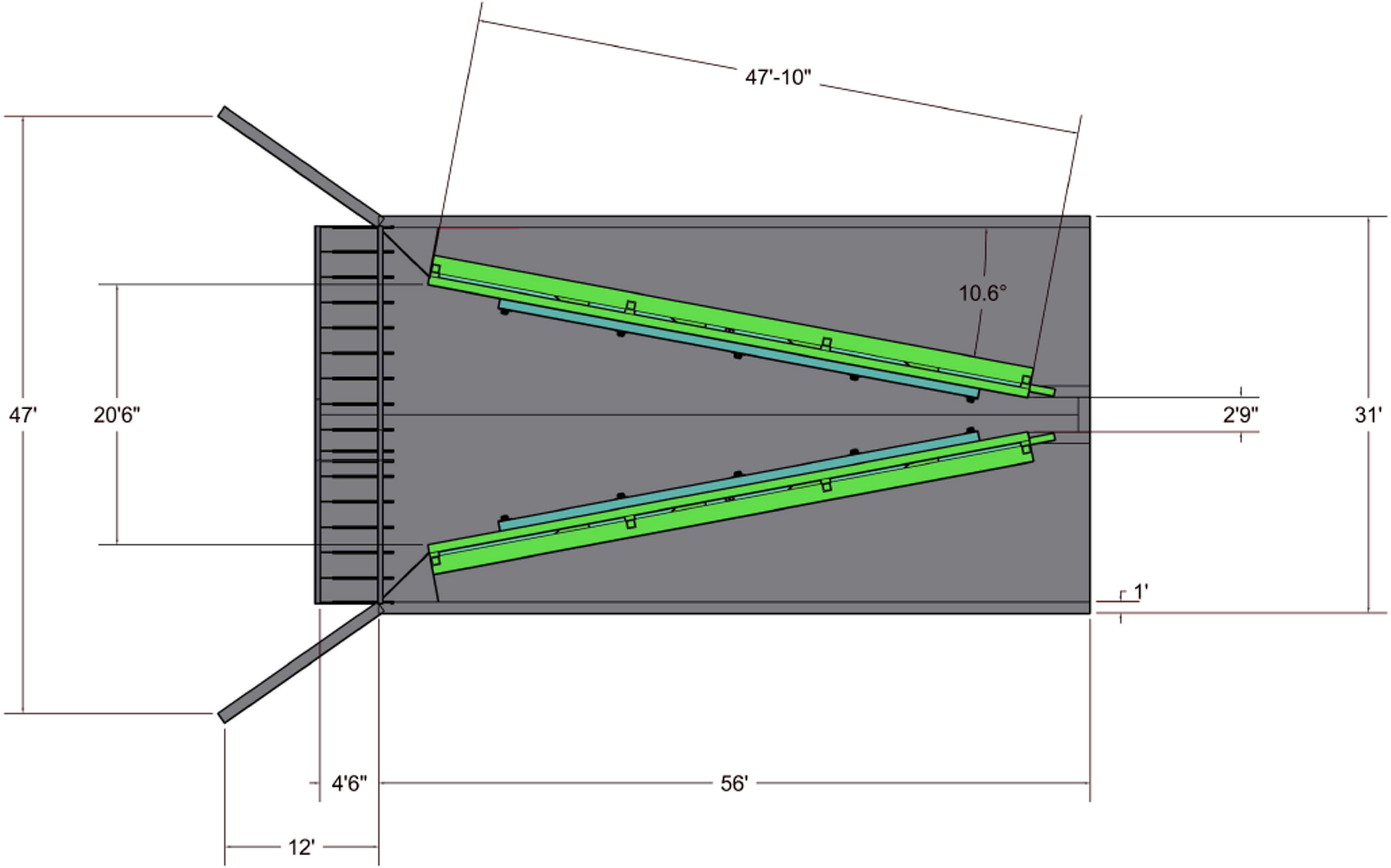

PLAN VIEW

HIGHLAND DITCH DIVERSION
MODIFICATION PROJECT (HDDMP)
PRELIMINARY DESIGN ITERATION 3
PREFERRED DESIGN

HIGHLAND DITCH DIVERSION
RIO BLANCO COUNTY, CO

EXHIBIT E5
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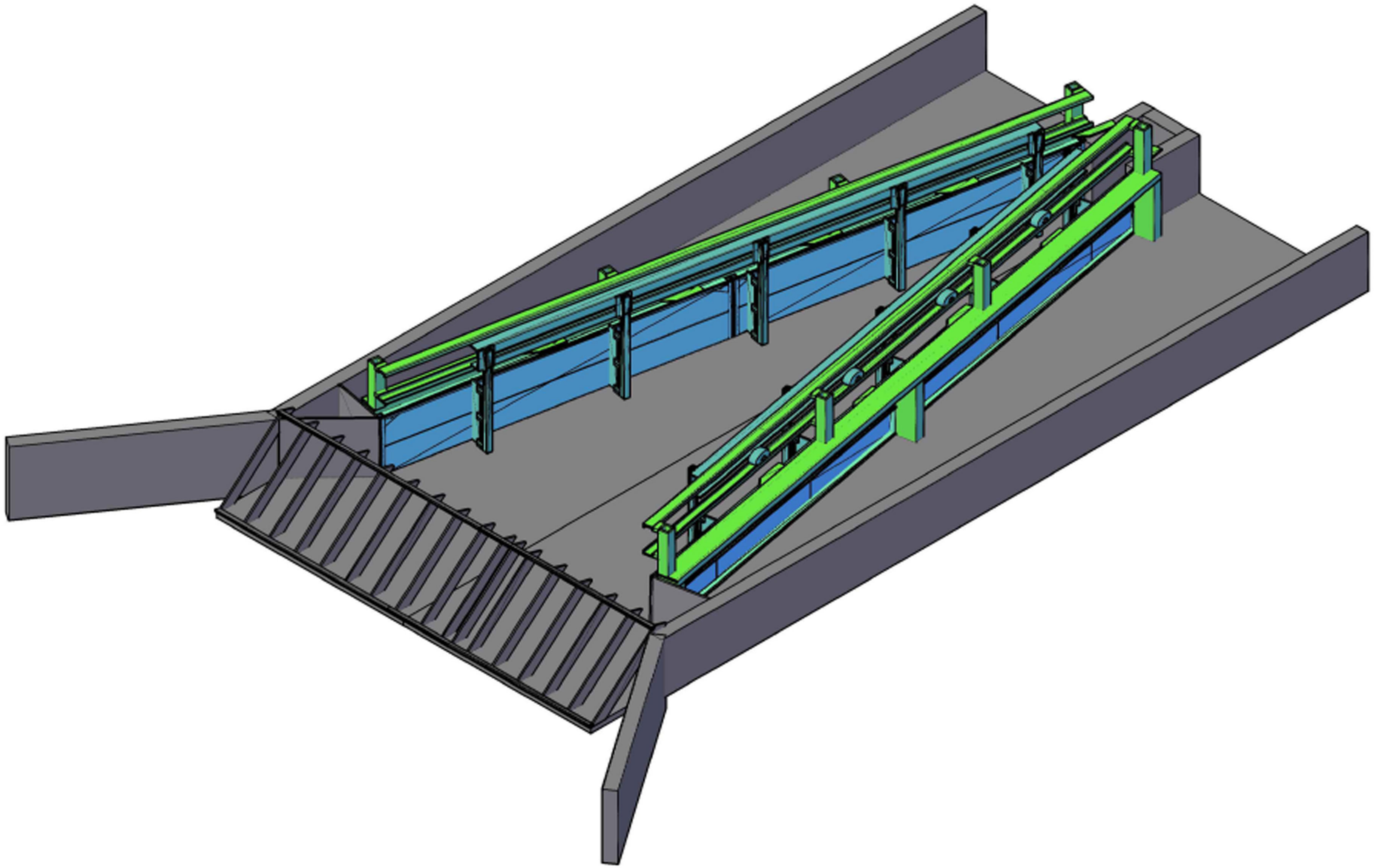

ISOMETRIC VIEW

ONEFISH ENGINEERING, LLC

HIGHLAND DITCH DIVERSION
MODIFICATION PROJECT (HDDMP)
PRELIMINARY DESIGN ITERATION 3
PREFERRED DESIGN

HIGHLAND DITCH DIVERSION

RIO BLANCO COUNTY, CO

EXHIBIT E6

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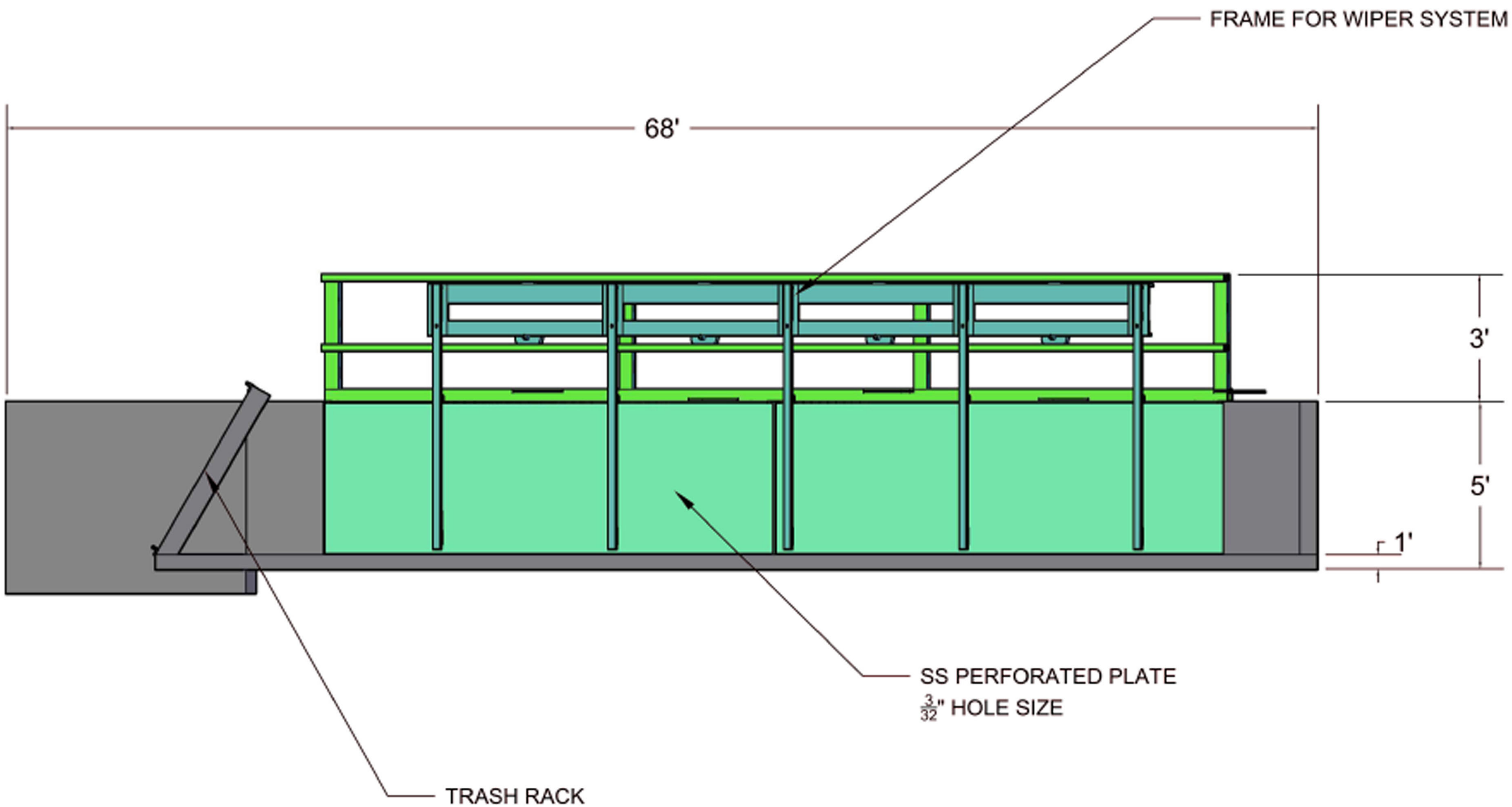

ELEVATION VIEW ALONG CENTERLINE

FISH SCREEN TO BE OPERATED
WITH SOLAR POWER.

ONEFISH ENGINEERING, LLC

HIGHLAND DITCH DIVERSION
MODIFICATION PROJECT (HDDMP)
PRELIMINARY DESIGN ITERATION 3
PREFERRED DESIGN

HIGHLAND DITCH DIVERSION

RIO BLANCO COUNTY, CO

EXHIBIT E7

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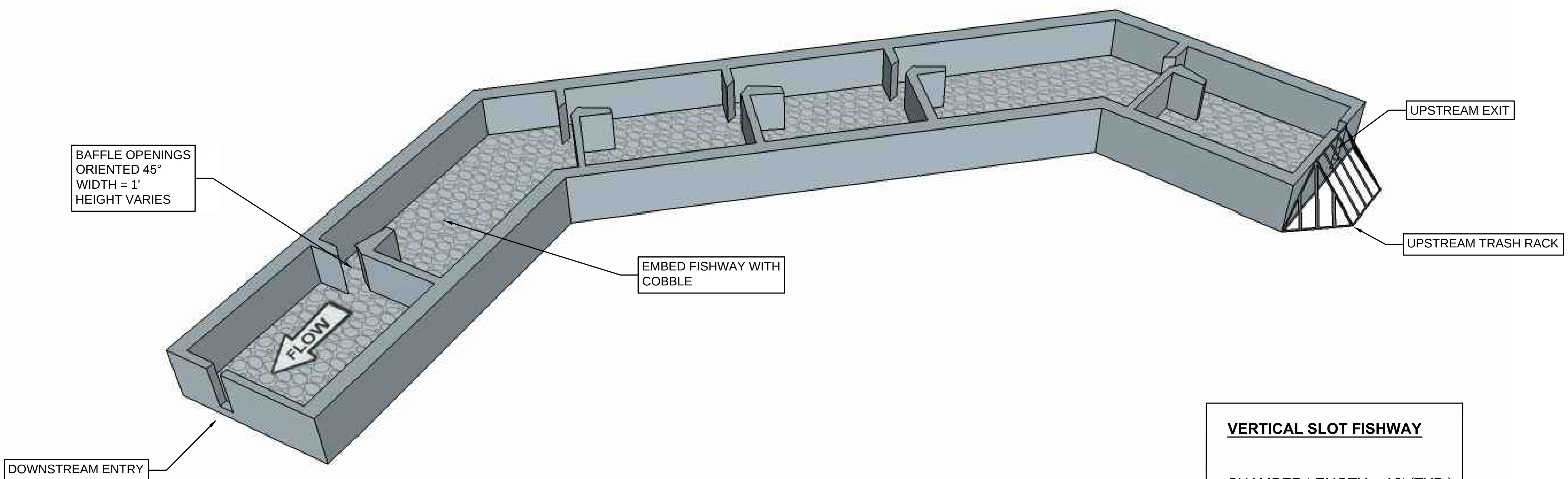

VERTICAL SLOT FISHWAY

CHAMBER LENGTH = 10' (TYP.)
CHAMBER WIDTH = 8'
CHAMBER HEIGHT (VARIES)
SLOT OPENING WIDTH = 1'
OPENING ANGLE = 45°
TOTAL LENGTH = 74'
D.S. INVERT = 989.15'
U.S. INVERT = 991.4'
SLOPE = 0.03

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HIGHLAND DITCH DIVERSION
MODIFICATION PROJECT (HDDMP)
PRELIMINARY DESIGN ITERATION 3
PREFERRED DESIGN (FISHWAY DETAIL)

HIGHLAND DITCH DIVERSION

RIO BLANCO COUNTY, CO

EXHIBIT E8

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DATE: Oct. 2015

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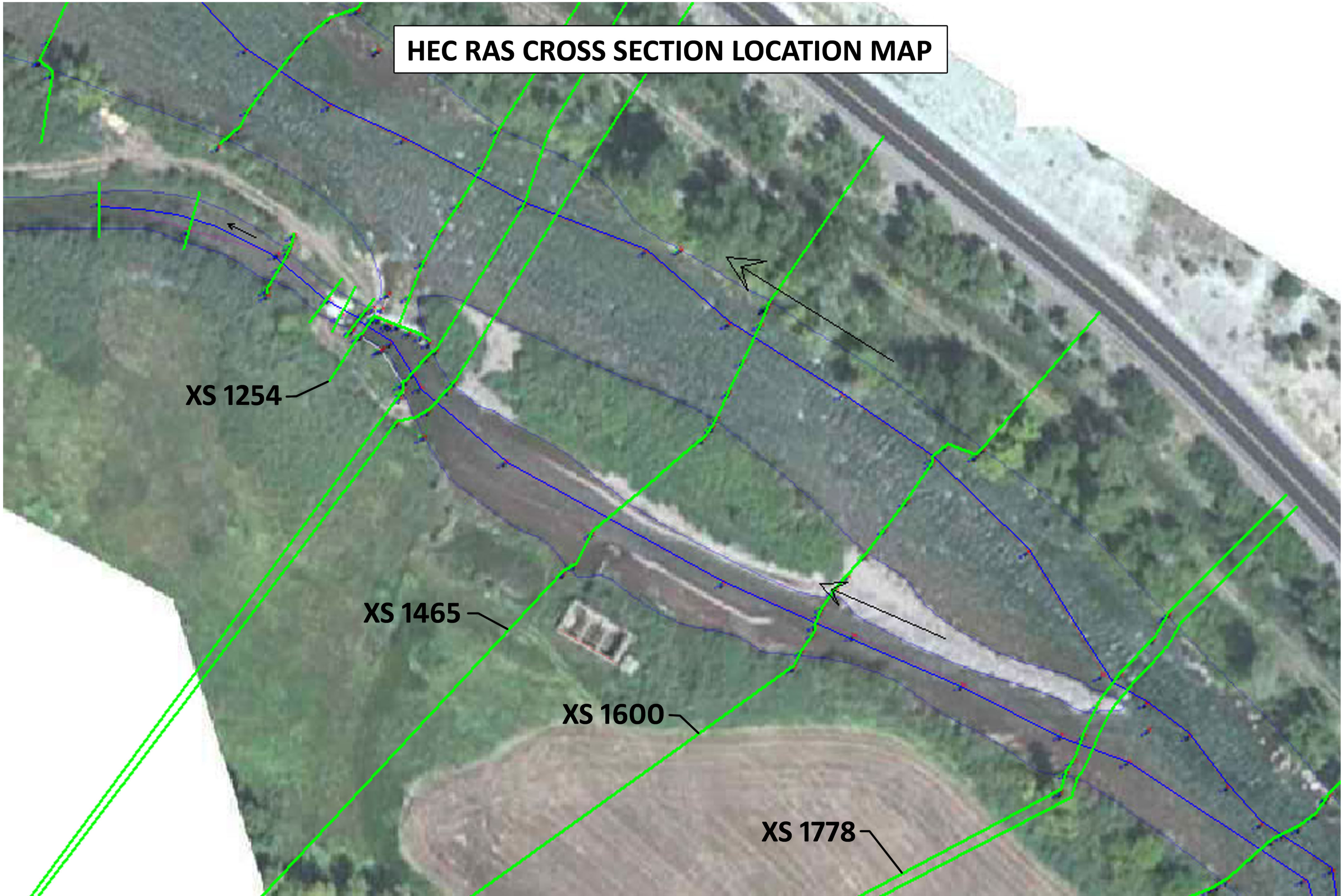

EXHIBIT F

SCALE : N.T.S.
DATE: Jun. 2015

HIGHLAND DITCH DIVERSION

RIO BLANCO COUNTY, CO

HIGHLAND DITCH DIVERSION
MODIFICATION PROJECT (HDDMP)
HEC-RAS SECTION LOCATIONS

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ONEFISH ENGINEERING, LLC
Fish Screening and Passage Engineering
916 Pioneer Avenue
Fort Collins, CO 80521
Phone (970) 237-0739
Web www.OneFishEngineering.com
Email Suzanne@OneFishEngineering.com

Highland Ditch
Fish Screen 30% Design Report

November 18, 2015

Figure 1 - Aerial View of Highland Ditch Diversion

Prepared For:

Corey Engen
FlyWater, inc.
Phone: (970) 217-3182
Email: corey@flywater.com

Prepared By:

OneFish Engineering, LLC
916 Pioneer Ave, Fort Collins, CO 80521
Phone: (970) 237-0739
Email: suzanne@onefishengineering.com

Table of Contents

Executive Summary

Colorado Parks and Wildlife is heading an effort with various stakeholders to develop and construct an improved irrigation system for the Highland Ditch on the White River which will continue to provide uninterrupted irrigation water deliveries without the damaging impacts of fish entrainment and impeded upstream fish passage.

The Upper White River supports seven native fish species, including two State Threatened and Endangered Species, the Flannelmouth sucker and the Colorado River cutthroat trout. Studies by Colorado Parks and Wildlife have found that the Highland Ditch diversion causes entrainment issues for all fish species present.

This document begins by presenting site background information and explaining the selection of the initial design, it then discusses the issues leading to the withdrawing of that recommendation. Finally, it explains the recommendation and the work performed to reach a 30% design. It includes construction cost estimates for the selected screen design.

Background

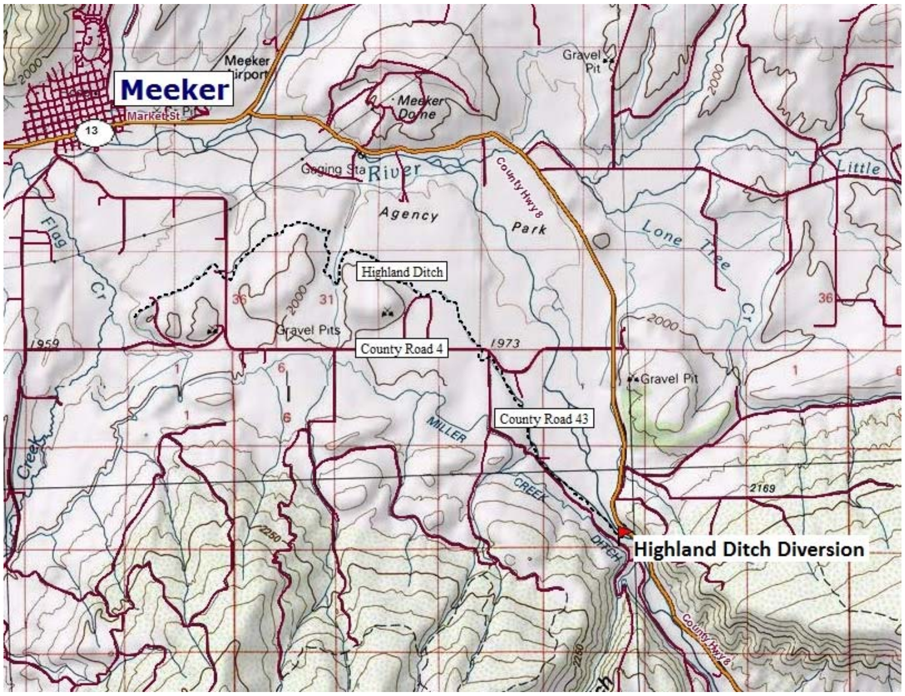


Figure 2 - Area Map for the Highland Ditch Diversion

The Highland Ditch Diversion is located on the White River approximately 6.5 miles southeast of the town of Meeker in western Colorado (Figure 2). The Highland Ditch has a direct flow water right of 250 cfs and serves over 5,000 irrigated acres.

Colorado Parks and Wildlife (CPW), the Highland Ditch Company, Trout Unlimited, High Lonesome Ranch/K Bar T Ranch, Wheeler/Elk Creek Ranch, TNC, USFWS, Colorado Water Conservation Board Roundtable, NRCS and the Colorado Water Trust are partnering to improve both upstream passage and downstream (entrainment) passage at the Highland Ditch Diversion.

Providing fish screening at the Highland Ditch diversion would save thousands of fish from entrainment and mortality every irrigation season.

The primary goals of the fish screening aspect of the project are to:

- Select and design downstream fish passage (screening) at the ditch, saving thousands of fish from entrainment and mortality every irrigation season.
- Maintain uninterrupted water delivery to the ditch to match the ditch company's direct flow water rights.

Existing Site Conditions

Diversion Dam

The diversion dam consists of two parts. A year-round island in the White River diverts a portion of the river flow to the left channel, which can then be either diverted into the ditch, or can be returned to the White River. A second part of the diversion is a gravel push up dam that is installed as the proportion of water delivered to the left channel needs to be increased. The push up dam either partially or completely spans across the right channel of the White River dependent upon irrigation needs. See Figure 3.

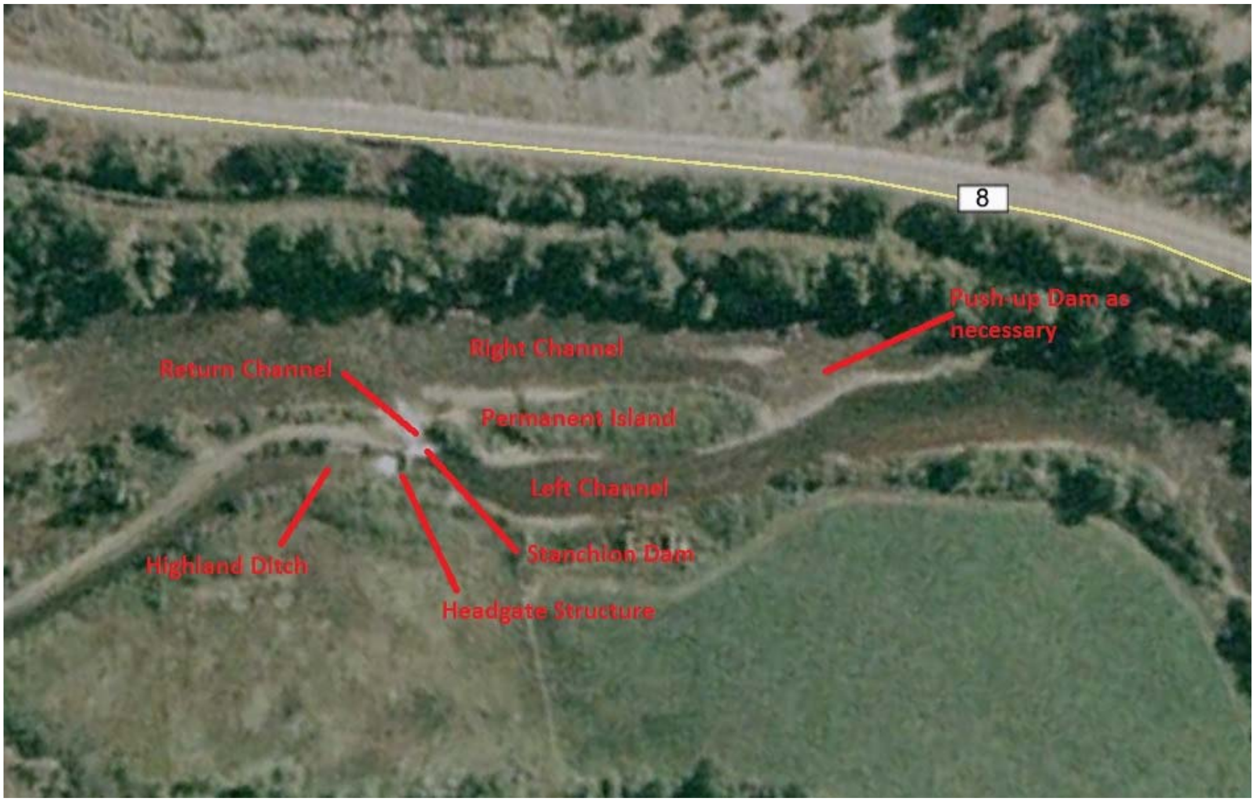


Figure 3 – Existing Site Conditions

Return Channel and Stanchion Dam

At the downstream most point of the island is the return channel, see Figure 3. This channel allows water that was diverted into the left channel to be returned to the main White River if it will not be used for irrigation purposes. This return channel can be dammed with the use of an existing stanchion dam which is roughly 35 feet across. This dam uses wooden flash boards that can be adjusted to create more water head on the upstream side of the head gate structure. It appears that the maximum height of the dam is roughly 3 feet above the existing ground level in the left channel.

Figure 4 - Existing Stanchion Dam

Head Gate Structure

The head gate structure consists of three rectangular slide gates which are used to regulate the amount of flow entering the Highland Ditch. The existing structure is a headwall made from concrete with concrete abutments. Culverts through the headwall are regulated with slide gates. There is a grouted spillway between the head gates and main canal.

The access road to the head gate structure and stanchion dam follows the north side of the ditch and ends at the right abutment of the head gate structure. Approximately 700 yards down the ditch is a 10 foot Parshall flume for measuring the amount of diverted water.

Figure 5 - Existing Head Gate Structure

Hydrology

The White River flows from the west side of the Flat Top Mountains in a westerly direction to its confluence with the Green River in Utah. At the site of the Highland Ditch diversion, the White River drainage area is close to 650 square miles. The hydrograph follows a typical snow melt pattern. Typically there is low flow through the winter months, in late April snowmelt begins, peak flows typically occur in late May and then flows tapper off throughout June and July and return to a base flows again in August. There are no significant water storage reservoirs affecting water delivery.

White River Flows

The U.S. Geological Survey has continuously operated gauge *09304200 White River above Coal Creek, Colorado* since 1961. This gauge is located approximately 2.4 miles downstream of the Highland Ditch diversion. There appear to be no diversions or large tributaries between the Highland Ditch diversion and the stream gauge; consequently, this gauge provides good proxy data for examining the potentially available bypass flow at the diversion.

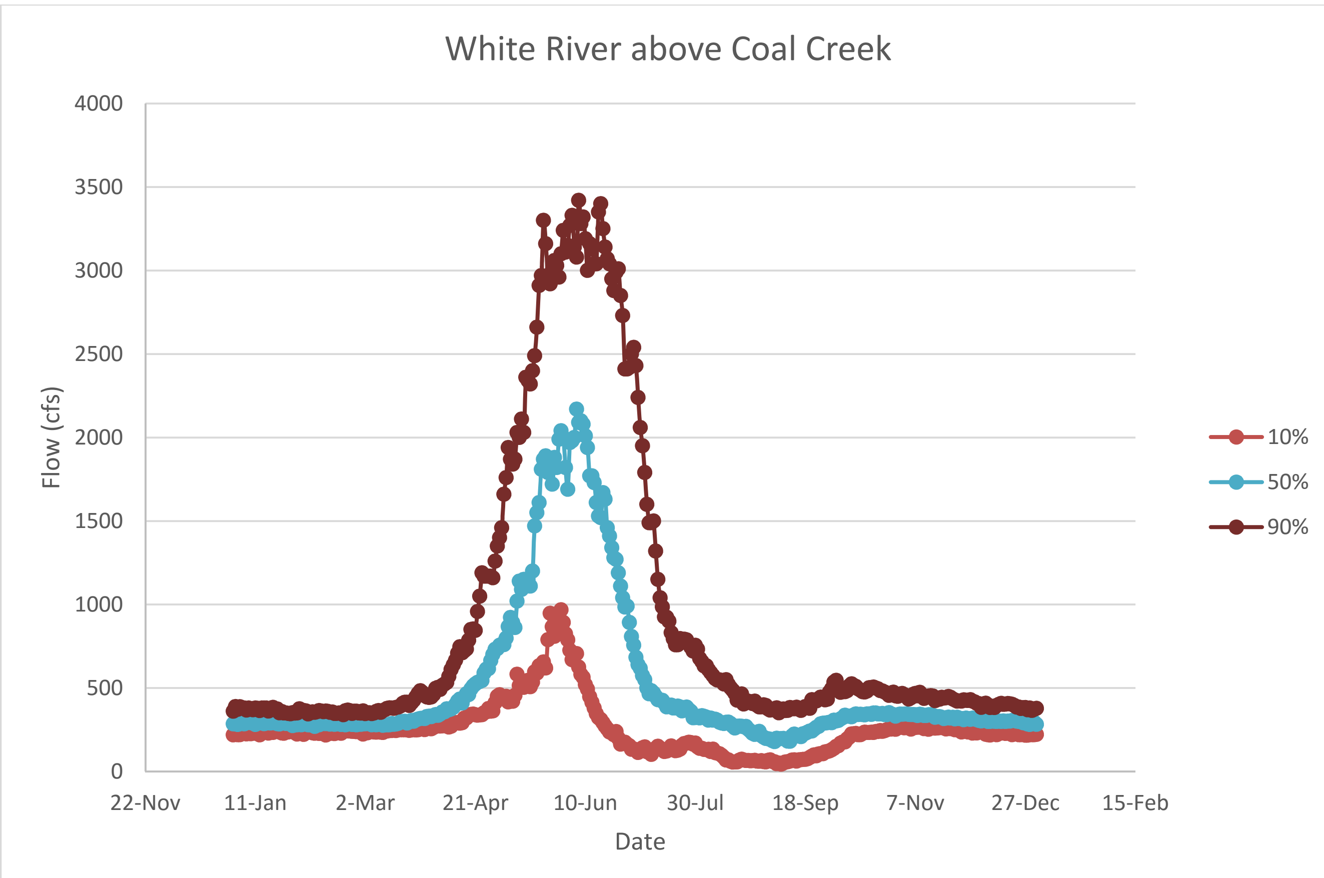


Figure 6 – White River Flow Data

Figure 6 shows average flow data from the White River gauge data.

- The blue line shows the average flow data, which can be seen to peak at around 2000 cfs in early June. This graph can be thought of as representing a typical flow year.

- The brown line is the 10% exceedance data, which can be thought of as the flow in a wet year. In a wet year, the flow can peak at over 3000 cfs.
- The red line is the 90% exceedance data, which can be thought of as the flow in a dry year. In these years, the flow might never exceed 1000 cfs.

Looking at the flow data, there are several other values of interest.

- Maximum flood flow
  - Flood flows are important to be sure that the fish screen is designed to avoid damage during these high water periods.
  - The highest flow level ever recorded by the USGS gauge was 5740 cfs (6/26/1983).
- Minimum flow levels
  - Minimum flow levels are important as they reveal how much flow will be available for the operation of a bypass used to move fish into the White River, after the ditch flow has been diverted during base flows.
  - In dry years, the flow below the Highland Ditch diversion sometimes drops below 80 cfs – but only rarely goes below 30 cfs. The lowest recorded flow values are 6.5 cfs.
  - Although these numbers are not the exact numbers present at the Highland ditch and do not account for irrigation return flow, transpiration and other variables, they are accurate enough to indicate that even in dry years, there is only a small amount of time where there would not be enough water available for the operation of the fish screen.

Ditch Flow

Approximately 700 yards downstream of the head gate, a Parshall flume is installed in the Highland Diversion ditch. The Colorado Division of Water Resources periodically records flow data from this flume; this provides an excellent record of diverted flow for this ditch.

- Records have been kept since at least 1950, and continue to be recorded.
- The number of samples per year varies. In a typical recent year, the flow is recorded on approximately 25 occasions.

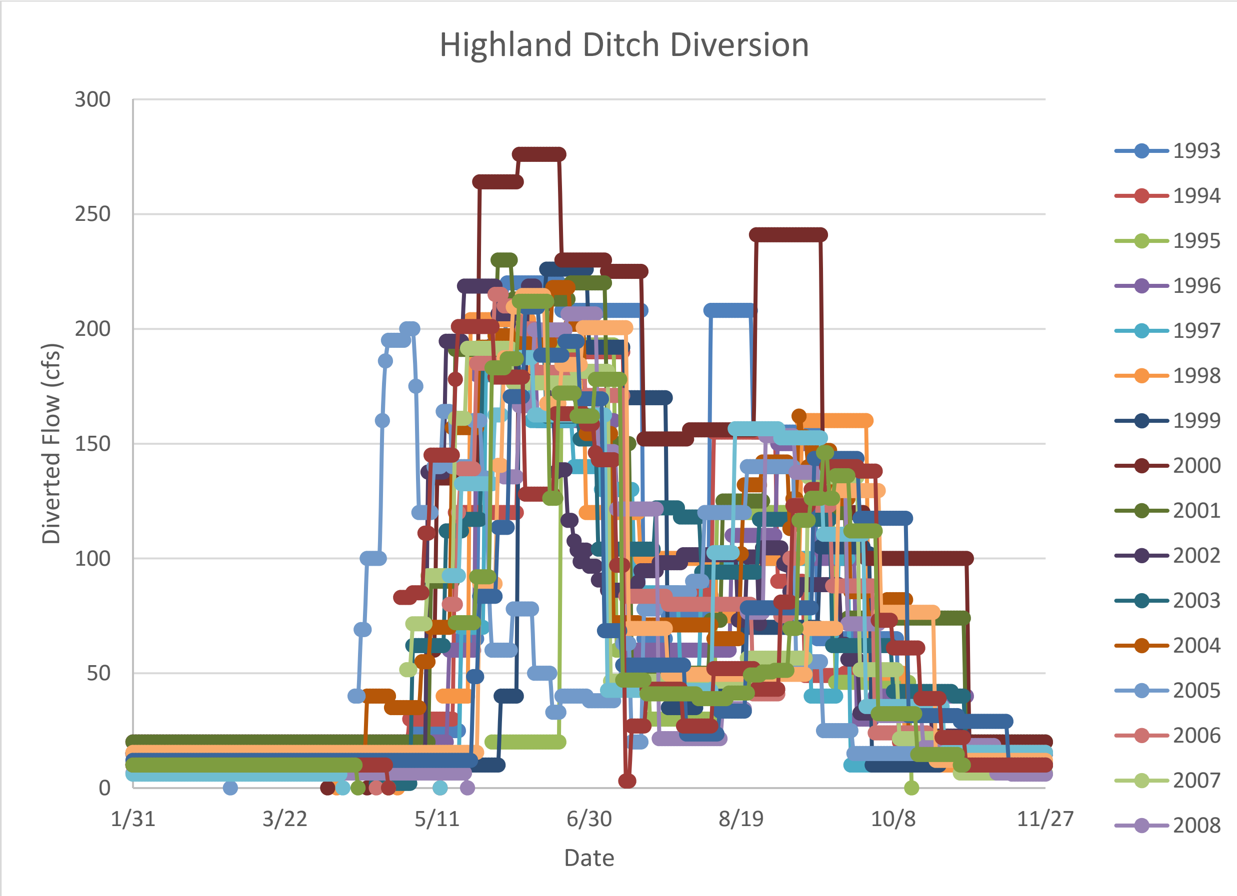


Figure 7 - Highland Ditch Flow Data

Figure 7 shows all recorded and interpolated flow data from 1993 through 2013.

- Maximum flows are typically between 200 and 250 cfs.
- It appears that less flow is diverted later in the irrigation season.

Hydrology Conclusions

When looking at hydrology data for a fish screen site, there are several key questions that need to be answered.

- What should be the design flow for the fish screen?
- If a fish screen is located in the ditch, is there enough difference in water surface elevation between the ditch and creek during all creek flows to effectively return fish to the creek?
- What amount of the water remains in the river past the diversion?

Fish Screen Design Flow

Establishing an appropriate design flow for a fish screen ensures that the screen provides reliable water delivery, without being oversized and more costly than necessary.

Head Difference for Fish Screen Bypass Flow

An on-canal screen must have a bypass pipe or channel to return fish from the ditch to the creek.

- For the bypass to operate properly, the water surface elevation in the ditch must be higher than the water surface in the river where the bypass pipe delivers fish back into the creek (which will be downstream of the diversion).
- Measurements of water surface elevations indicate there will be enough head for the bypass to operate properly with the exception of some peak run-off times.

Fraction of Flow Diverted

The fraction of flow diverted, or more exactly the amount of flow remaining in the river after the diversion, is important for determining fish screen operations. Two of the types of screens considered for this site utilize bypass flow.

- A coanda screen utilizes bypass flow for moving debris and fish over the top of the screen. Without sufficient bypass flow and depth of water on the screen, fish become either stranded or suffer from descaling.
- A vertical plate located on-canal needs bypass flow to return the fish through a pipe to the White River. Without this egress, fish become trapped between the head gates and fish screen where eventually they will tire of swimming against the current and will become impinged on the fish screen and suffer injury or death.

Based on comparison of the gauging station located on the White River and the flows recorded in the ditch, there are a few years and times when there will not be sufficient water to operate a fish screen return.

- In the past 25 years, there have been a total of 380 days where the flow past the diversion has been less than 80 cfs. That is 6% of the time.
    - An on-canal vertical plate would operate without issue at this flow.
    - A coanda screen would provide only marginal fish protection at this level.
- In the past 25 years, there have been a total of 134 days where the flow has been less than 30 cfs. That is 2% of the time.
    - The on-canal vertical plate would operate with some issue at this flow.
    - The coanda screen would not effectively screen fish with this low a bypass flow.
        - 60% of the days less than 30 cfs occurred in 2002.
        - 20% of the days less than 30 cfs occurred in 2004.

Available Head (Water Depth)

A key design question when evaluating any water diversion is whether or not there is sufficient head, often measured as water depth, to deliver the required water into the irrigation ditch. This is particularly important when considering the installation of a fish screen, which will cause some amount of head loss. It is important to be sure that the head loss from the fish screen will not impact the ability to deliver water. This head loss can be accounted for and mitigated through the design of the diversion.

To evaluate the available head, depth sensors both upstream of the head gate structure in the left channel of the White River and also downstream of the head gates in the ditch.

- The stanchion dam was in place during this time period.

- The water surface elevation in the left channel was typically 4 feet higher than the water surface elevation in the ditch.

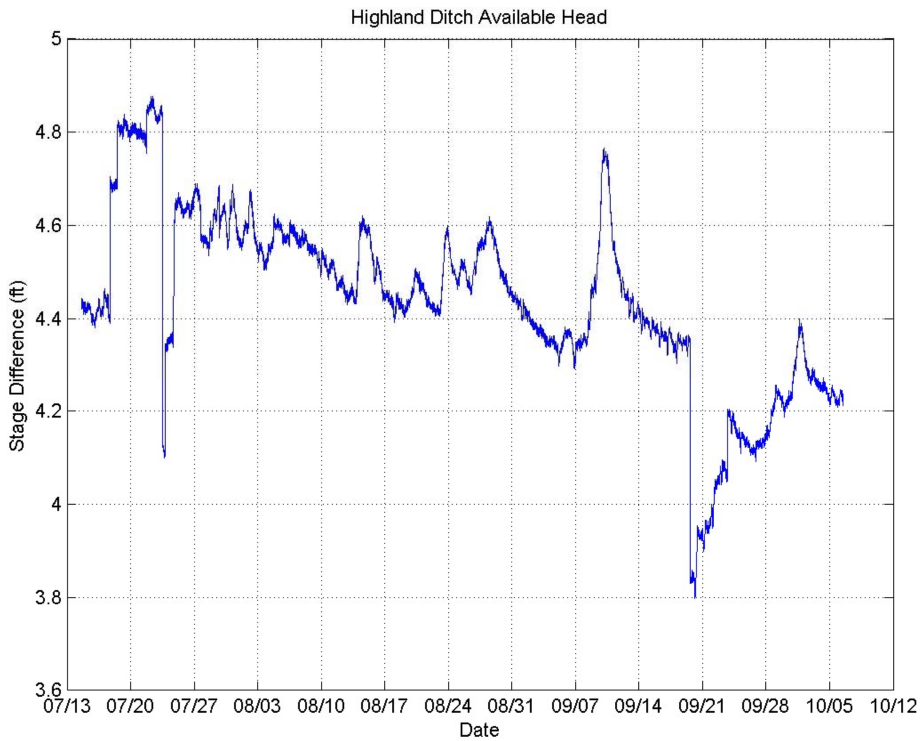


Figure 8 – Difference in Water Surface Elevations (Head)

Initial Assessment and Recommendation

In December of 2014, OneFish Engineering put together an Alternatives Analysis to assist stakeholders in understanding the benefits and tradeoffs with the various types of fish screens that could be used for screening at Highland Ditch. It was also intended to assist stakeholders in selecting an appropriate screen to move forward with design. A copy of the text and table comparing the recommended screens is included below:

For the fish screen, the design team developed three viable options: a coanda screen located in the side channel of the White River that leads to the diversion, multiple cone screens located in the side channel of the White River that leads to the diversion, or a vertical screen with a brush system located in the canal immediately downstream of the head gates. The table below summarizes the key tradeoffs between these alternatives.

	Coanda Screen	**Cone Screens**	**Vertical Plate with Brushes**
Location	On-River	On-River	On-Canal
Pros	Fish never leave the river. No external power necessary. No moving parts.	Fish never leave the river.	Protected from large debris. Easy Access.
Cons	Requires more bypass flow than other screen types. Requires more head than other types of screens.	Needs to be protected from large debris. May require winter removal. Difficult to access.	Fish leave river and return via bypass pipe. Lack of sufficient head during peak runoffs means some fish stranded and some sediment accumulation.
Estimated Cost	$450,000	$1,200,000	Va 0.4 ft/s: $1,000,000 Va 0.8 ft/s: $720,000

As noted in this table – a coanda screen would be significantly less money than the other types of screens recommended. However, it is also noted that this type of screen “Requires more bypass flow than other screen types. Requires more head than other types of screens.”

Coanda Screen Design

Coanda screens have been used for trash filtering at diversions for many years, however, coanda screens are infrequently used as fish screens. There are few sites where sufficient bypass flow is available to safely move fish over the screen without risk of fish descaling or becoming stranded on the screen.

Another reason for the limited use of coanda screens as fish screens was the lack of design information. However, in 2001 the Bureau of Reclamation began testing coanda screens and developing design equations. Subsequently a computer program was developed utilizing the equations to expedite the design of coanda screens.

The first step in the design process was to determine if a screen could be developed at this site that would safely transport fish over the screen. The results of this design process were summarized in a memo titled *Highland Ditch Coanda Screen Low Flow* dated January 14, 2015.

The next step in the design process was to determine the layout of the coanda screen. At this point in the design process, it was determined that the original notion to place the screen perpendicular to the head gates at the location of the stanchion dam presented an issue. Visual cues during the site visit and results of flow monitoring during the irrigation season of 2014 suggested that a pipe placed through the existing dike on the east side of the canal would be feasible. Calculations and further study, however, showed that it would not be feasible. This caused the layout to change as shown in Figures 9 and 10.

Figure 9 - Original placement of Coanda Screen

The original orientation of the coanda screen was especially beneficial because it provided an easy means of bypassing the fish screen and diverting water if an issue with the fish screen were to arise. Rather than using the fish screen, one would just open up the existing head gates (or upgraded head gates) and take the water directly from the left channel. Additionally, when using the coanda screen, controlling the amount of flow into the ditch was fairly straightforward and just necessitated using the proposed head gate on the screen.

Figure 10 - Altered placement of the Coanda Screen

As one can see, the easy method of bypassing the fish screen in the original layout was no longer an option. The resolution to this issue was to place head gates on the back of the structure so that water could just flow under the screen. Additionally, it was no longer straightforward to control the flow into the ditch. Several possibilities exist to control the water into the ditch, but without water user input this was not resolved.

Recommendation of Withdrawing Coanda Screen

Once into the design process, it was determined that a static diversion structure (rock weirs, regrading and riffles in the White River) would produce flooding of the White River in high flows. This flooding is independent of the coanda screen and is a consequence of replicating the existing conditions. However, it was determined that a coanda screen would necessitate an additional one foot minimum of raised water surface. The additional one foot would exacerbate the situation and result in additional flooding.

Rectifying this situation would require a dynamic diversion. Research into an Obermeyer weir had begun, but involved additional modeling efforts. Due to these complicating flooding factors and the issues with operation that had arisen with the new orientation of the coanda screen, it was recommended to withdraw the coanda screen from further consideration.

Two screen recommendations remained, cone screens located upstream of the head gates or placing a vertical plate screen in the ditch.

Option: Cone Screen Located On-River in Left Channel

Figure 11 - Cone Screen Layout

- The screens would be located just upstream of the head gate, in the pool above the stanchion dam (3).
- The cone screens would be 12' in diameter and 3' tall. They would be cleaned by a brush system and powered by a solar electric system.
- There would be six screens.
- A concrete floor and flow channel would be extended from the existing head gate wall to support the screen installation.
- When complete, there would be two control gates.
  - The existing head gate would remain in its current location, and would continue to regulate the flow into the ditch.
  - A second bypass gate would be located upstream of the primary head gate. This gate would normally be closed, and would only be opened if it was necessary to bypass flow around the fish screen.
- Under normal operation, water would flow down through the cone screen, through the concrete channel and then through the existing head gates.
- In the event of a problem with the cone screen, the bypass gate could be opened to allow water to be diverted without passing through the cone screen.
- Some type of protection would need to be installed to prevent larger debris, such as logs and trees, from hitting the screen. This would likely be a floating debris boom secured to pilings driven into the channel bottom.

Some additional details about a cone screen, not shown in the drawings, are below.

- A solar system would be installed near the screen structure.

- In addition to solar panels, the installation will have an enclosure to house batteries and a control panel to regulate the operation of the screen.

- It may be necessary to remove the screen from the water during the winter to avoid potential damage from ice in the creek.

The preliminary construction cost estimate for the cone screens is $1,200,000.

Option: Vertical Plate Screen Located On-Canal

Figure 12 - Vertical Plate Screen

(Note: Depiction is from original analysis and has since been updated and relocated)

- The screen will be located on the ditch, below the spillway far enough that the water is no longer turbulent, but still within easy access of the head gate.
- The concrete structure would fit into the existing ditch cross section, without requiring any significant expansion of the size of the ditch.
- A bypass channel ~80 feet long will return fish from the ditch back to the river.
- The screening area would consist of multiple screen plates each ~6 feet in length.
    - The brushes move slowly along the screen and sweep any debris downstream to the bypass pipe where it is carried back to the river.
- Walkways would be installed to allow easy access to all parts of the structure.

Some additional details about a vertical flat plate screen installation are listed below.

- A solar system will be installed near the screen structure.
    - In addition to solar panels, the installation will have an enclosure to house batteries and a control panel to regulate the operation of the screens.
- Sediment accumulation in front of the screen could be a concern. This issue relates to the issue of available drop between the canal water surface and the river water surface.

Enough drop needs to be present to move water through the bypass pipe at a rate of greater than 2 ft/s to insure that sediment is moved away from the front of the screen.

- The design of a flat plate screen can be modified based on the specified maximum approach velocity at the screen.

The stakeholder group decided to move forward with a vertical flat plate screen.

30% Design

Screen Location

Figure 13 - Proposed Screen Site

During initial conversations the screen site was located immediately downstream of the Highland ditch head gates. This is common practice to allow for easier maintenance of fish screens. However, because head gate operations require driving along the ditch and turning around and driving out along the ditch, it does not appear to be overly onerous to place the screen approximately 750 feet down the ditch (see Figure 13).

There are several advantages to this location.

- It drops the fish into a location with moving water. This decreases the amount of predation that occurs when fish are moved into a concentrated spot in a river. Moving water helps prevent piscivorous species from lingering indefinitely at the bypass outfall.

- Enough elevation has been gained above the river that periods of backflow from the river is going to be minimal. This is important because backflow prevents the movement of fish and debris from the ditch to the river.
- Rises in head from the fish screen are going to have almost no effect on current operations and will not require additional head from what the ditch company currently uses to push water into the ditch.
- Additional head can be created without affecting diversion operations. This will allow for utilizing a greater depth of water at the screen which will decrease the length and cost of the screen versus if the screen were located at the head gate.

Screen Size

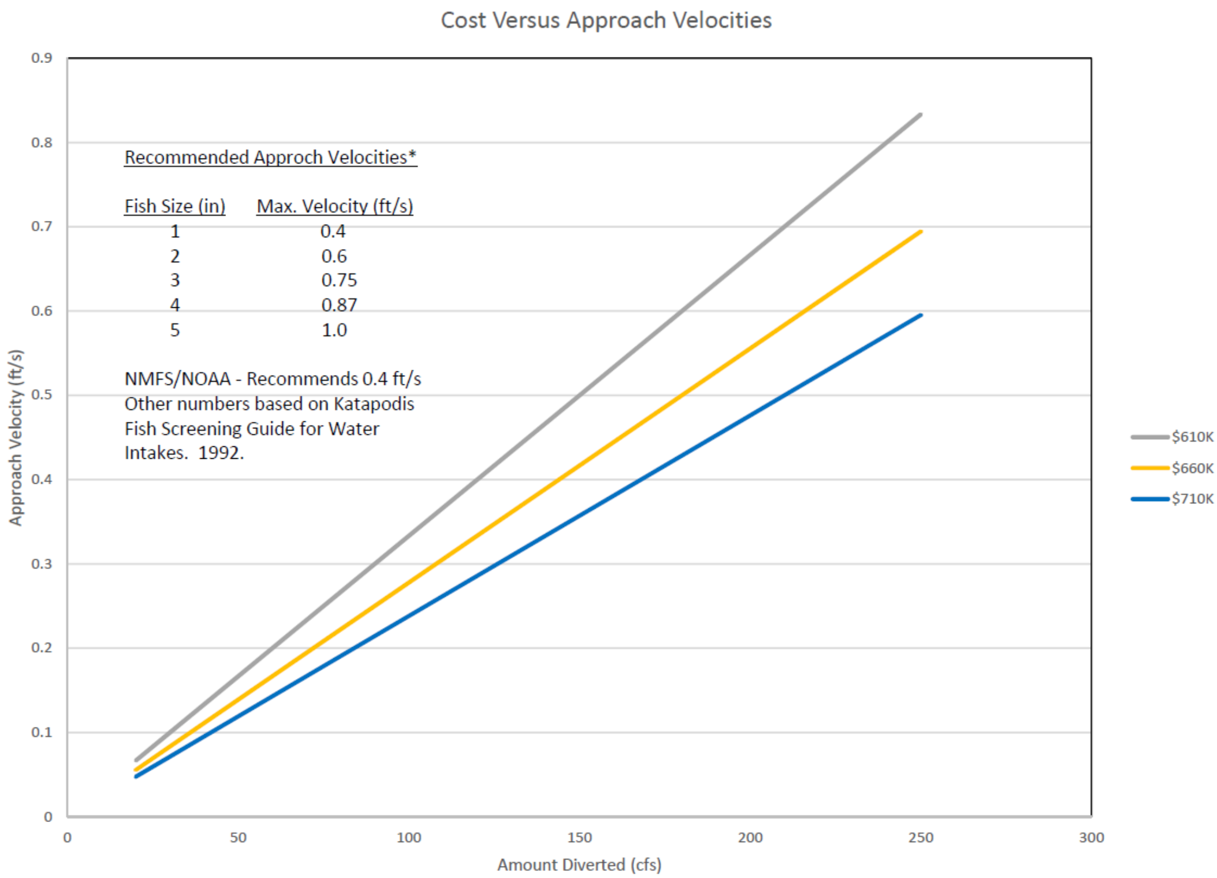
As was discussed in the original alternatives analysis, approach velocity is an important variable that determines both the size of the screen and the potential for injury to fish. Several screens, such as a coanda screen, a farmer's screen or a cone screen, have fixed approach velocities. This can be limiting in that it provides no room for compromise and cost savings. Vertical flat plate screens, however, can work under a variety of approach velocities, allowing for variation of screen size and cost.

The majority of the research to date has been performed on anadromous salmon. Design criteria published in the National Marine Fisheries Service manual entitled *Anadromous Salmonid Passage Facility Design* require using an approach velocity of 0.4 feet per second or less. This requirement is based on the assumption that fry-sized salmonids and low water temperatures are present at all sites. However, this also assumes a 98% survival rate of fish encountering a screen. (Section 16.2, Manual; NMFS 2008).

Current regulations and criteria do not exist for the species located in the White River. This enables the stakeholders to consider the cost to benefit ratio.

OneFish Engineering's field experience has shown that a vertical flat plate screen's ability to effectively clean debris and deliver water begins to deteriorate at approach velocities above 0.8 feet per second.

The graph shown below was developed to assist stakeholders select an appropriate approach velocity at differing water levels for the screen.



As of writing, a final decision has not been agreed upon by stake holders, but varies between the $610K screen size and the $710 screen size. A comparison of the two screen sizes is given in the table below. Please note these are preliminary numbers and will change over the course of the design.

	$710K	$610K
Approach Velocity @ 250 cfs (ft/s)	0.6	0.8
Approach Velocity @150 cfs (ft/s)	0.35	0.5
Length of Screen (ft)	140	100
Length of Structure (ft)	70	50
Width of Structure*	30	30
Total Concrete (CYDS)	120	90
Cost per CYD	$1300	$1300
Total Concrete Cost	$156,000	$117,000
Cleaning System Cost	$75,000	$65,000

Solar Power Cost	$80,000	$80,000
Bypass Pipe & Gate Cost	$12,000	$12,000
Walkways and Railings Cost	$40,000	$35,000
Screening and Framing	$100,000	$85,000
Misc.	$65,000	$60,000
Mobilization (12%)	$63,360	$54,480
20% Contingency	$118,272	$101,696
Total Cost	$710,000	$610,000

*Width of Structure does not include wing walls.

NMFS (National Marine Fisheries Service). 2011. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon.

EXHIBIT H
GLOSSARY OF TERMS

Fish Passage - Design of diversion structures and engineered channels such that water depth and velocity allows target fish species to migrate from the downstream to the upstream end of any manmade obstruction.

Intake Channel - The southern channel that has the pushup dam at the upstream end and terminates at the ditch headgate and concrete return flow apron. Flow at the downstream end of the intake channel either enters Highland Ditch, or returns to the White River.

Headgate -The wooden and concrete gate structure at the upstream end of the ditch that can be opened or closed to allow or exclude flow into the ditch by operation of three adjustable wheel gates.

Blocker Board Structure -Structure at the top of the return flow apron that can be fitted with blocker boards in order to divert more flow toward the headgate and ditch

Turnout - The point at the downstream end of the intake channel where water is diverted into the ditch. The Highland Ditch turnout has a headgate to regulate flow.

Return Flow Channel - The short section of channel at the downstream end of the intake channel that returns flow not taken into the ditch back to the White River. The existing return flow channel is a barrier to upstream fish passage.

Push Up Dam - Diversion structure made from native bed material, typically built using a bulldozer to push existing bed material up into a dam or weir to divert water from the White River into the intake channel.

Thalweg - The longitudinal line that follows the deepest part of a river or channel.

Invert - The bottom of a pipe, channel or weir crest.

Static Diversion Structure - A fixed diversion structure such as a concrete weir that cannot be adjusted to alter crest elevation or open flow area.

Dynamic Diversion Structure - A diversion structure that has a moveable gate to alter crest elevation or open areas, and divert more or less flow.

Freeboard - The distance from the water surface to the top bank of a river, channel, or lake.
When zero freeboard is exceeded, flooding occurs.

Exhibit I: Vertical Flat Plate Screen On-Canal O&M

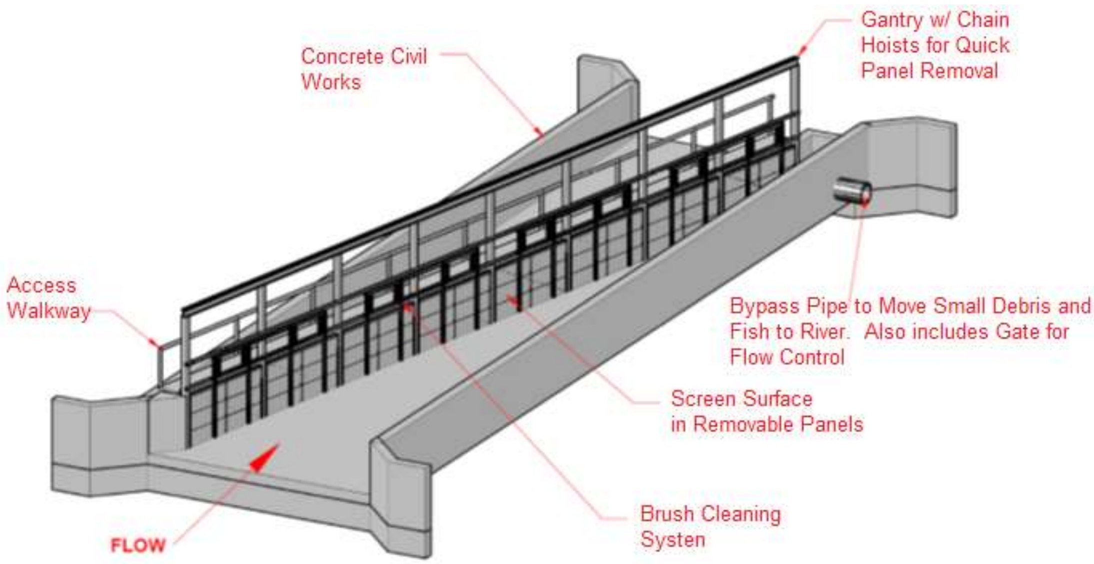


Figure 1 – Vertical Flat Plate Fish Screen Overview

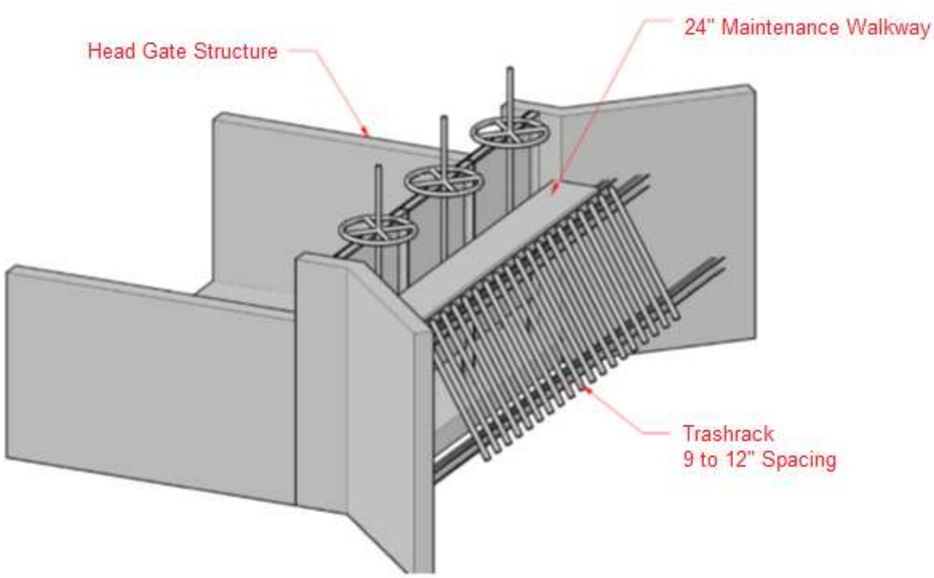


Figure 2 - Debris Rack Overview

Operation and Maintenance Features

- The fish screen structure will have walkways installed in key locations to allow complete access to the screen for maintenance and operation.
- A gantry frame with chain hoists will be installed along the length of the fish screen.
- The screen will be fabricated in panels
  - These panels can be easily lifted out of the structure using a chain hoist installed on the screen and gantry to allow continued diversion in the event of a problem with the screen.
- A bypass pipe moves fish, debris and sediment to the river
  - A control gate located on the bypass pipe allows water users to balance the water diversion needs with the necessity to return fish, debris and sediment to the river.
- A walkway will be installed on the head gate structure for improved access to head gates and for access to large debris trash rack.
- A trash rack will be installed at the head gate structure to capture larger debris that would adversely affect the head gates and the fish screen.

Operations

- Adjustment to the screen and cleaning system should not be necessary during the irrigation season.
- Periodic observation should be made of the cleaning system to insure that no debris is blocking the operation of the brushes and that the system is working properly.
- Periodic hand cleaning of the screen (with a broom) may be necessary when excess debris is coming down the White River. (Fall = leaves, Spring = excess debris in the water).
- It may be necessary to adjust the bypass pipe flow during the season when there are changes to the amount of water being diverted in the ditch.
- It may be beneficial to "flush" the ditch system of sediment after large run-off events that carried excessive sediment into the ditch.
  - Fully opening the bypass pipe for a short period of time will flush accumulated sediment from in front of the screen.
- Cleaning debris off of the head gate trash rack should be performed at the same frequency as is currently performed.

Maintenance

Start of Season

- If the screens were raised in the hoist system, lower the screens.
  - Important, DO NOT run the cleaning system if ice remains in the ditch.
- Inspect the brush system to ensure there is nothing is blocking the motion of the brushes.

- Open the solar power system and ensure that the charge controller and system power switch are both turned ON.
- Open the control panel and turn the system power ON.
- Switch the Timer ON. Watch the system through a few complete cycles to ensure everything is working properly.

End of Season

- Open the control box and turn the Timer and System Power switches to OFF
- Open the solar power system and turn the system power switch to OFF.
  - The solar panel, battery and charge controller can remain installed through the winter.
- Check to see condition of sacrificial anodes.
  - If sacrificial anodes need replacing, order and replace.

Operation and Maintenance Costs

Task	Frequency	Labor	Parts
Observation of Screen Operation	1-2x per week during irrigation	~5 min	$0
Hand Brush of Screens*	1-2x per week during high debris flows	~30 min	$0
Adjustment of Bypass Flow	1-2x per month during irrigation	~15 min	$0
Flushing System of Sediment	1-4x per month during irrigation, dependent on sediment in system	~15 min of work, 1-2 hours of flushing time	$0
Debris Removal from Trash Rack	1-2x per week during irrigation season	~30 min	$0
System Start-Up	1x per season	~1 hour	$0
System Shut-Down	1x per season	~1 hour	$0
Replacement of Sacrificial Anodes	1x per 3 years	~1-2 hours	$50.00
Replacement of Motors (4 Motors Total)	1x every 5-10 years	~4 hours	$2,000 (for 4 motors)
Replacement of Batteries	1x every 10-20 years	~8 hours	$5,000 - $10,000 (for entire set)
Replacement of Solar Panels	1x every 20-40 years	~8 hours	$5,000 (for entire set)

**If during periods of high flows the screen becomes clogged more often that people are out there, the screens can be pulled up and out of the way. It will be important to work with biologists to determine if there is a likelihood of entrainment during these times.